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# Improving agricultural productivity in Thailand

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IMPROVING AGRICULTURAL PRODUCTIVITY IN THAILAND

by

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IMPROVING AGRICULTURAL PRODUCTIVITY IN THAILAND

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The main concern of this essay is to identify management strategies to improve the agricultural productivity of the highly weathered soils typical of tropical regions. The study first explores the physical context of Thai agriculture. It then considers the social, political, and economic context of environmental and agricultural change in Thailand from antiquity to the present. Focusing upon the deterioration of rural systems of production and the plight of Thai farmers, the essay explores measures that have been undertaken to enhance agricultural production, typically with little success. Particularly promising is the prescriptive application of mineral amendments-essentially mimicking natural processes of soil formation that would lead to higher levels of fertility. It is hoped that this study will contribute, however modestly, to a more secure and prosperous future for Thailand's farming families.

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## PREFACE

This essay addresses questions that have come to command the attention of many academics, international aid agencies, governments, and non-governmental organizations. Solutions for improving agricultural production on highly weathered and infertile soils of tropical regions have proven to be illusive. This paper considers unconventional ameliorant management strategies, where previous approaches have fallen short, and have been described as experiments that have been repeated all over the world with no end in sight.

Inspiration for this research comes through David Sims, vice-president of the Saraswathi Foundation in Bangkok, Thailand. The objectives of the foundation have expanded beyond providing schools and lunch programs for poor, rural children, to include strategies that provide monetary assistance and advice to farming families struggling to survive in the wake of flawed governmental programs that promote Green Revolution technologies as a panacea to rural poverty.

The question posed was: "How many tons of compost should be dug into each *rai* of land to improve soil fertility?"[1] As implied above, there is a plethora of literature on the subject, but no easy answers. Intuitively, one should first ask: "what are the properties of the compost, as well as that of the soil on which they will be applied?" There is no easy answer to this question either.

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[1]A *rai* is an area measurement equivalent to 1600 square meters, 0.16 hectare, or about 2/5 acre.

Further complicating this issue, intensive cultivation in Thailand over the last fifty years has been accompanied by increasing use of chemical fertilizers, insecticides, and fungicides—collectively acting as a biocide in soils, as well as in the collective environment. Under these conditions, certain soil nutrients become depleted while others may build up to toxic levels, causing local variations in soil fertility from area to area, field to field, and within the same field. Cases of improper management practices have led to soil sterility, land abandonment, and thus competition for new land which has become a very scarce commodity.

Attempting to address this dilemma and define the problems that contemporary agrarians face, scale of observation and factors governing current issues need to be addressed from temporal and spatial perspectives. Soil diversity is a function of the scale of observation contingent upon parent material, topography, climate, hydrology, past management practices, and crops cultivated, over time. Hence, attention will focus initially upon the inherently interdependent systems of the physical resource base for agriculture: geology, geomorphology, climate, hydrology, soils, and flora and fauna.

The cultural-historical evolution of the region will then be considered. Particular attention will be devoted to the impact of human activity upon environmental systems over time. Discussion will focus upon the kingdom of Thailand. From the emergence of the early Siamese state, issues of politics, culture, economics, and development have all shaped the manner in which the resource base has been exploited, the same resource base that supports Thai agriculture.

The final chapter will explore the literature related to agricultural production in Thailand. It is clear that past research efforts have fallen short and that new directions must be identified. It will discuss the innovative concept of using finely ground rock dust to ameliorate infertile soils, as an additional management tool that has been overlooked by researchers. Geological resources are available within the kingdom, and their utility as an amendment to infertile soils should not be overlooked.

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# CHAPTER 1

# INTRODUCTION

Agriculture has evolved over millennia, perhaps from multiple points of origin. Ancient innovation by semi-sedentary cultures that domesticated plants and animals eventually led to man's control of breeding, sometimes becoming so complete that the domesticates could not survive without human intervention.[2] By securing a food supply through agriculture and animal husbandry, large human population increases became possible.[3] Early forms of agriculture were relatively sustainable, as agriculturalists were nomadic, or practiced swidden agriculture, never taxing resources of any one area beyond the ability of natural processes to replace them. As populations increased and civilizations became more complex, so did agricultural practices and strategies to manage them.

The sedentary cultures that emerged from the evolution of agriculture placed an ever-increasing demand upon resources. In 1798, Thomas Malthus warned that the human population would eventually outstrip its capacity to produce enough food to sustain its growing numbers. Malthus based his assumption upon what he regarded as simple, mathematical fact, without the foresight of the phenomena of the "Green

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[2]Richard A. Watson and Patty Jo Watson, "The Domesticator of Plants and Animals," in *Prehistoric Agriculture*, ed. Stuart Struever (New York: The Natural History Press, 1971), 9.

[3]Ibid., 3, 8.

Revolution" and "Globalization." Unfortunately these phenomena have come at great expense in terms of environmental degradation and uneven development.[4]

Agricultural production and distribution of food is humanity's most important enterprise,[5] and plays a critical role in the economies of the world. In both developed and "developing" countries, rural populations rely upon agriculture for their livelihood. Asia, as a region, already has an acute land shortage and is on the verge of a food deficit.[6] The projected population of 4.2 billion people in the region by 2025 cannot be sustained with available land resources.[7]

In Southeast Asia, there is a sharp imbalance between the forces of economic growth, and those of environmental conservation. The region has become renowned as one of the most dynamic zones of the global economy, and an area in which the environment is being rapidly depleted of scarce natural resources.[8] Forests have been cleared at alarming rates for more than a century, favoring quick economic gain over more traditional and sustainable livelihoods. Thailand, for example, has been described as the "…epitome of uneven development… and exhibits some of [Southeast Asia's] most striking signs of spatial disparity and environmental stress."[9]

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[4]Michael J. G. Parnwell and Raymond L. Bryant, eds. *Environmental Change in Southeast Asia: People, Politics and Sustainable Development.* Global Environmental Change Series III. (London: Routledge, 1996), *passim.*

[5]Paul R. Ehrlich, Anne H. Ehrlich, and Gretchen C. Daily, "Food Security, Population, and Environment," *Population and Development Review* 19 (1993): 1.

[6]Hari Eswaran, P.F. Reich, F.H. Beinroth, and E. Padmanabhan, "Major Land Resource Stresses in Relation to Sustainable Agriculture in Asia," Taipei, Taiwan, Food and Fertilizer Technology Center. 1999: 1 (Accessed online January 20, 2005). Available: http://www.fftc.agnet.org

[7]Ibid.

[8]Parnwell and Bryant, *Environmental Change in Southeast Asia,* 330.

[9]Ibid., 341.

Thailand has little chance to expand cultivated land, owing to the fact that land suitable for agriculture is already under production. Existing cultivable and abandoned lands will need to be developed to meet the future needs of agriculture.[10] It has been estimated that only 6.6 percent of Thailand's total land area is relatively free of major agricultural constraints.[11]

Agricultural economics causes crops for human, animal, and fiber consumption to be exported from the site of crop growth. A large portion of this becomes refuse spatially concentrated in urban areas, commercial livestock facilities, or is discarded as industrial waste.[12] Documented loss of vital soil elements owing to agricultural production and dispersion of biomass is well represented in the literature, the consensus being that soils are being "mined."[13]

No soil can sustain the constant depletion of critical elements for plant life under agricultural cultivation. To correct the imbalance between soil nutrient export and import, it is necessary to replenish nutrients that have been removed or lost. Addition of highly soluble N-P-K fertilizers and organic residues alone is not sufficient to counteract

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[10]Parida Kuneepong and Rungsarit Boonsin, "Land Development and the Problems to be Solved," Land Development Department Report, Bangkok (Accessed online July 15, 2003). Avalible: http://www.ldd.go.th

[11]P. Moncharoen, T. Vearasilp, and H. Eswaran, "Land Resource Constraints for Sustainable Agriculture in Thailand," in *Sustaining the Global Farm: Selected Papers from the 10th International Soil Conservation Organization Meeting, May 24-29, 1999,* eds. Diane E. Stott, Rabih H. Mohtar, and Gary C. Steinhardt (West Lafayette, Indiana: 2001), 179 (Accessed online April 11, 2003). Available: http://topsoil.nserl.purdue.edu/nserlweb/isco99/pdf/ISCOdisc/tableofcontents.htm

[12]S.W., Buol, "Sustainability of Soil Use," *Annual Review of Ecology and Systematics*, 26 (1995): 25.

[13]Peter van Straaten, *Rocks for Crops: Agrominerals of sub-Saharan Africa* (Nairobi, Kenya: ICRAF 2002), 4; Andrew Goudie, *The Human Impact on the Natural Environment*, 5th ed. (Cambridge, Massachusetts: MIT Press, 2000), 160, 175, 180; Buol, "Sustainability of Soil Use," 32; W.S. Fyfe, B.I. Kronberg, O.H. Leonardos, and N. Olorunfemi, "Global Tectonics and Agriculture: A Geochemical Perspective," *Agriculture, Ecosystems and Environment* (1983): 391; Martin Witkamp, "Soils as Components of Ecosystems," *Annual Review of Ecology and Systematics* 2 (1971): 105.

elemental loss. Chemically processed fertilizers have been designed for high nutrient, high cation-exchange capacity soils of temperate latitudes, and do not respond favorability in soils that are highly leeched, have low cation-exchange capacity, and low ability to hold nutrients.[14]

The majority of the Thai population depends upon agriculture as its main source of income, employment, and food security. Most rural agrarians are small independent households, relying upon soils and rain for life-supporting agricultural production. In this respect, most farmers are resource poor and operating on highly weathered and infertile soils-soils approaching the end of their evolutionary life.

It has become increasingly clear to farmers, non-governmental organizations, international aid agencies, academics, and governments that the conventional practice of farming in Asia, based upon the Green Revolution, is fatally flawed. The unsustainable nature of modern agriculture is manifesting itself in terms of stagnant or declining yields, increasing ecological degradation, and increasingly negative socioeconomic conditions.[15] Given the limited successes of Green Revolution technology in Thailand, and the inherent low fertility status in a majority of the soils, alternative strategies to ameliorate soils and increase yields need to be identified.

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[14]O.H. Leonardos, W. S. Fyfe, and B. I. Kronberg, "The Use of Ground Rocks in Laterite Systems: An Improvement to the Use of Conventional Soluble Fertilizers?" in Proceedings of an International Seminar on Laterite, October 14 – 17, 1985, Tokyo, Japan, ed. Y. Ogura. *Chemical Geology*, 60 (1987): 361.

[15]Michael Parnwell, "Rural Poverty, Development and the Environment: The Case of North-East Thailand," *Journal of Biogeography* 15 (1988): 199, 207.

## CHAPTER 2

## PHYSICAL THAILAND

### Geology

Thailand's location on the Asian Continent lies in part on the Yunnan-Malayan geosyncline, on the inner perimeter of the Southeast Asian Plate. The plate is being compressed from opposite directions by the Indian Plate and the Philippine Plate, from the west and east respectively. The kingdom straddles an area of latitude between two mountain systems, the Central Cordillera and the Cordillera of Annam, two of the four ranges that fan out southwards from the Yunnan Knot, beginning at about 28$^{o}$ N. The Central Cordillera includes Thailand's north, west, and southern mountain ranges, which continue into Malaysia. The Cordillera of Annam provides Thailand's eastern mountains, on the boundary with Laos and beyond.[16] The cordilleras cradle the depression on which Thailand is located, and define her five main watersheds.

In Northern Thailand, the Dean Lao and Thanon Thongchai ranges consist of granitic rock and complexes of gneiss, shales, schists, and limestones,[17] which solidified from magma, forty to 400 million years ago (mya).[18] The steep sided mountains rise off the valley floor (200 to 400 meters above sea level [masl]) up to Thailand's highest peak,

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[16]Parida Kuneepong, "FAO Gateway to Land and Water Information National Report: Thailand" (Accessed online December 5, 2002). Available: http://www.ldd.go.th/FAO/z_th/th.htm

[17]Norton Ginsburg, ed., *The Pattern of Asia* (New Jersey: Prentice-Hall, 1958), 395.

[18]Belinda Stewart-Cox, *Wild Thailand*, eds Ann Baggaley and James Harrison (London, England: New Holland Publishers, 1995), 20, 72.

Doi Inthanon, at 2,565 masl. South of these ranges, the Dawna and Tenasserim ranges trend southward and continue into the Kra Region, reaching altitudes of 2,100 masl. These ranges formed about sixty-five to fifty-five mya, when the Indian Plate separated from Eastern Gondwanaland and collided with Eurasia.[19] The ranges largely consist of granitic intrusives rimmed by upturned limestones and shales.[20] The Phuket and Nakorn Si Thammarat ranges in the southern peninsula are principally composed of limestones and granites. Karst limestone towers are evident in many locations throughout this region, including islands off the southwest coast.[21]

The northeast region is bounded on the west by the Petchabun and Dong Phaya Yen mountain ranges and in the south by the Dongrak Mountain Range, formed by the continual north-north-easterly force of the Indian Plate on Eurasia. These low-lying mountains rise to about 900 masl, and are all predominately sandstone, shale, or siltstone.[22] The northeast has been stable geologically for about the last 100 to 150 million years. Before this time the region was an intermittent inland sea.[23]

The structural geology of Thailand suggests four major changes-beginning in the Precambrian; again during the mid-Carboniferous; at the end of the Triassic Period; and

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[19]Courtillot et al., 1986; Beck et al., 1995, in Christelle Tougard, "Biogeography and Migration Routes of Large Mammal Faunas in Southeast Asia during the Late Middle Pleistocene: focus on the Fossil and Extant Faunas from Thailand," *Palaeogeography, Palaeoclimatology, Palaeoecology* 168 (2001): 340.

[20]Ginsburg, *The Pattern of Asia*, 395.

[21]Chaisang Phaikaew and Max Shelton, FAO Forage Resource Profile: Thailand, 1998 (Accessed online March 1, 2005). Available: http://www.fao.org/ag/agp/agpc/doc/sounprof/thailand.htm

[22]Ibid.

[23]Stewart-Cox, *Wild Thailand*, 19 – 20.

the last, toward the end of the Pliocene Epoch.[24] Figure 1 illustrates geologicial succession, showing evidence from the Precambrian throughout the Phanerozoic Eon.

## Geomorphology

Owing to past geological activity and Thailand's position between the Indian and Philippine plates, four main types of landforms are represented in the kingdom: mountain ranges, undulating plateau, alluvial flood plains, and coastal plains (Figure 2). Fluvial processes over millions of years have carved Thailand's mountain valleys, ridges, hills, and high peaks, leaving behind erosional landforms. Fragments of soil, regolith, and bedrock transported down slope by fluvial agents give rise to fans and alluvial terraces, characteristic of large, lower-lying areas of the country. Other depositional landforms created by wind and wave action are evident as beach and dune formations.

## Climate

Thailand's climate is tropical monsoonal and regulated by the Inter Tropical Convergence Zone (ITCZ). The ITCZ produces three seasons in northern, northeastern, eastern, and central Thailand, and two seasons in southern Thailand. Average annual temperatures range from about 20° C to about 34° C (Table 1).

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[24]Kuneepong, "FAO Gateway to Land and Water Information."

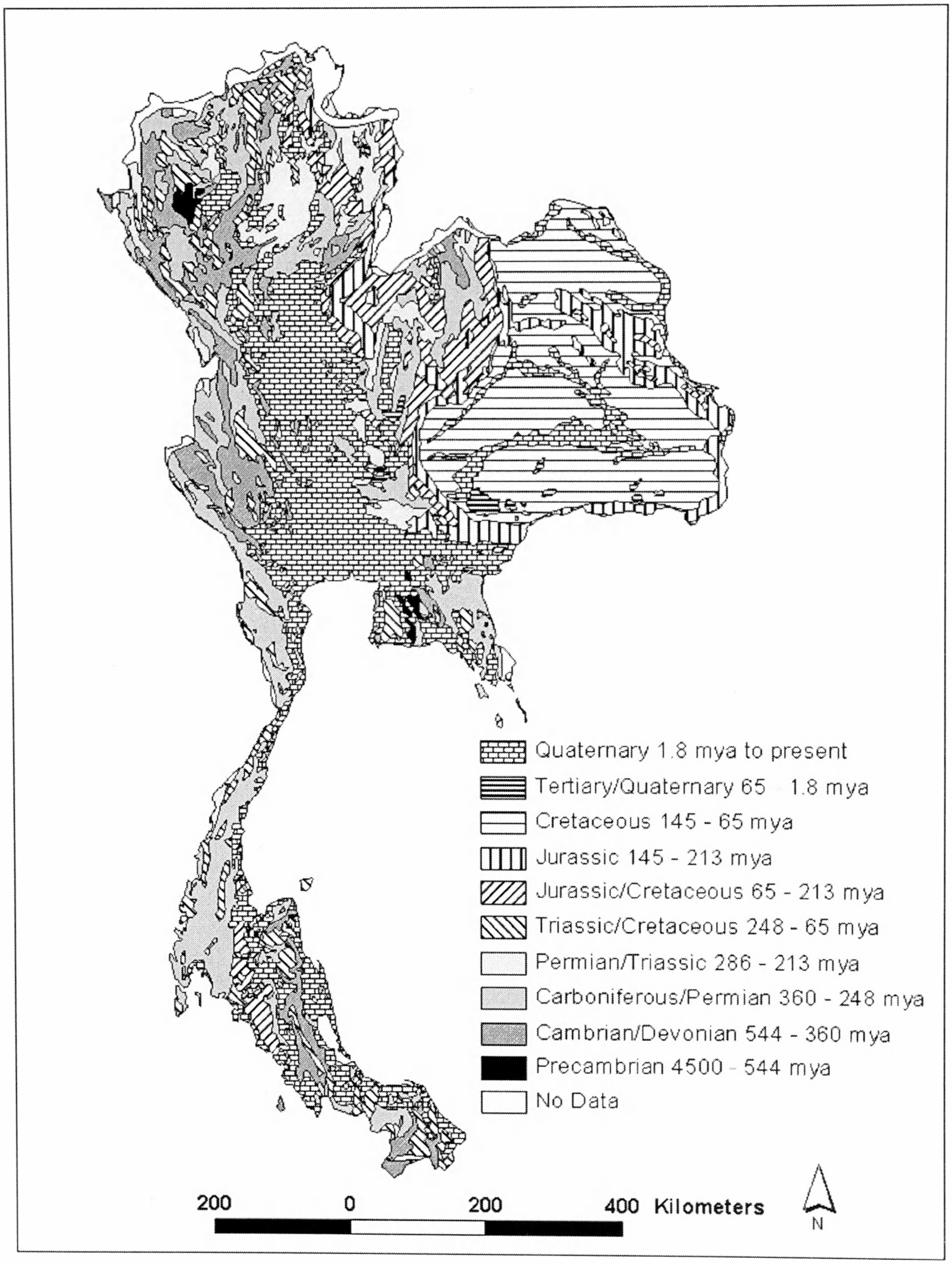


Figure 1. Geological Succession
*Source*: George T. Mason, Jr., and Arndt, Raymond E., 1996, Mineral Resources Data System, U.S. Geological Survey Digital Data Series DDS-20, U.S. Geological Survey, Reston, VA.

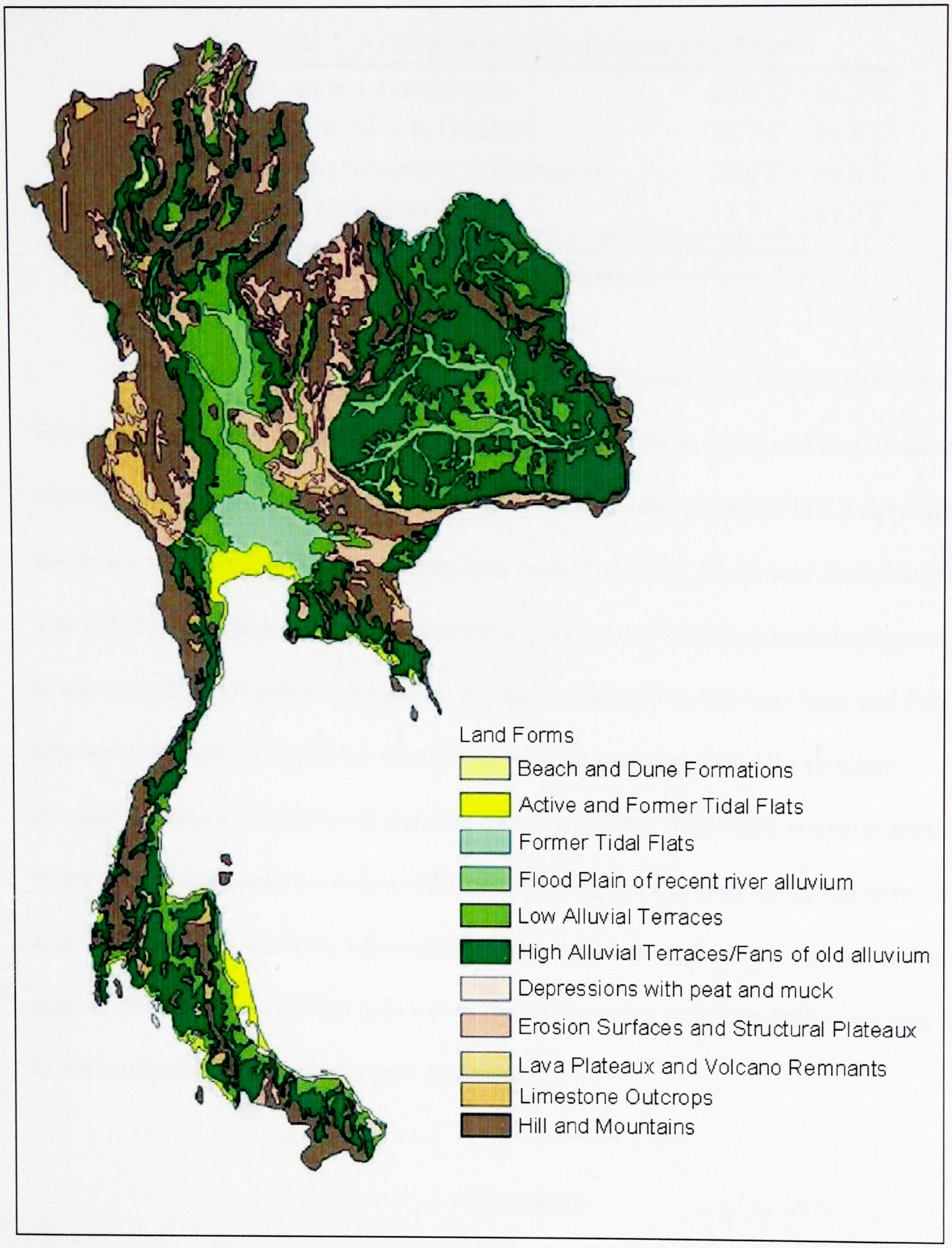


Figure 2. Main Landforms

*Source*: Land Development Department Bangkok, 1972.

Table 1. Average Annual Temperature by Season

| | |
|---|---|
| Average Annual Temperature | 22.5˚C – 32.3˚C |
| Rainy Season (May to October) | 24.1˚C – 31.8˚C |
| Cool Season (November to February) | 20.3˚C – 30.8˚C |
| Hot Season (March to April) | 23.2˚C – 34.2˚C |

*Source:* National Statistical Office, *Statistical Yearbook of Thailand 2003* (Bangkok: Ministry of Information and Communication Technology, 2002), 479.

The three season zone, which extends from Thailand's northernmost boarder to Phetchaburi Province in the southern peninsula, experiences a dry and wet monsoon climate, with the southwest monsoon starting around May when the ITCZ first arrives in the south, transporting humid air from over both the Indian Ocean and Andaman Sea. The ITCZ then follows the sun northward triggering convective rains bringing moisture to the rest of the kingdom. Southwest monsoons that arrive between May and July (except in the south) signal the start of the rainy season that lasts into October. November and December mark the start of a dry season. With only minor exceptions, every area of the country receives adequate rainfall, but the duration of the rainy season and the amount of rain vary substantially from region to region and with altitude and aspect. In general, rainfall is heaviest in the south with a maritime influence, and lightest in the northeast with its continental influence.

## Hydrology

Regional topography delineates five major watersheds in Thailand, all but two being shared with neighboring countries (Figure 3). In the northwest, the Pai and the Khun-Yuam river basins constitute part of the Salween watershed which drains west into

Burma. The Chao Phraya, the largest watershed contained entirely within the country, covers much of the north and central regions draining an area of about 178,000 $km^2$.[25] The major northern tributaries of the Ping, Wang, Yom, and Nan rivers, whose confluence at Nakhon Sawn (about 200 km north of Bangkok) form the Chao Phraya, which drains into the Gulf of Thailand.

Major rivers in the northeast include the Nam Chi and Nam Mun within the Mekong watershed, both draining the Mum Basin. The rivers originate in the Petchabun and Dong Phaya Yen Mountain Ranges to the west, which separate the northeast from the center of the kingdom. The rivers join in Ubon Ratchathani and drain eastward into the Mekong River, and onto the South China Sea. The Maeklong Basin in the northern peninsular Malaysian watershed drains an area of about 33,000 $km^2$.[26] The Khwae Yai and the Khwae Noi rivers originate in the mountains to the west near Burma, and join together to form the Maeklong River, about eighty kilometers from the Gulf of Thailand.[27] Other large rivers in the southern peninsular Malaysian watershed include the Tapi and Pattani rivers and, in the South-Southeast Coast, the Bang Pakong river.

Annual rainfall in the kingdom ranges from about 1,300 mm to 2,700 mm (Table 2). With the exception of the southern peninsula, approximately eighty-five percent of the precipitation falls during the rainy season, from about May to October, under the influence of the southwest monsoon. From October to January, the southern region receives over fifty percent of its annual rainfall during the northeast monsoon.

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[25]Kuneepong, "FAO Gateway to Land and Water Information."

[26]Ibid.

[27]Ibid.

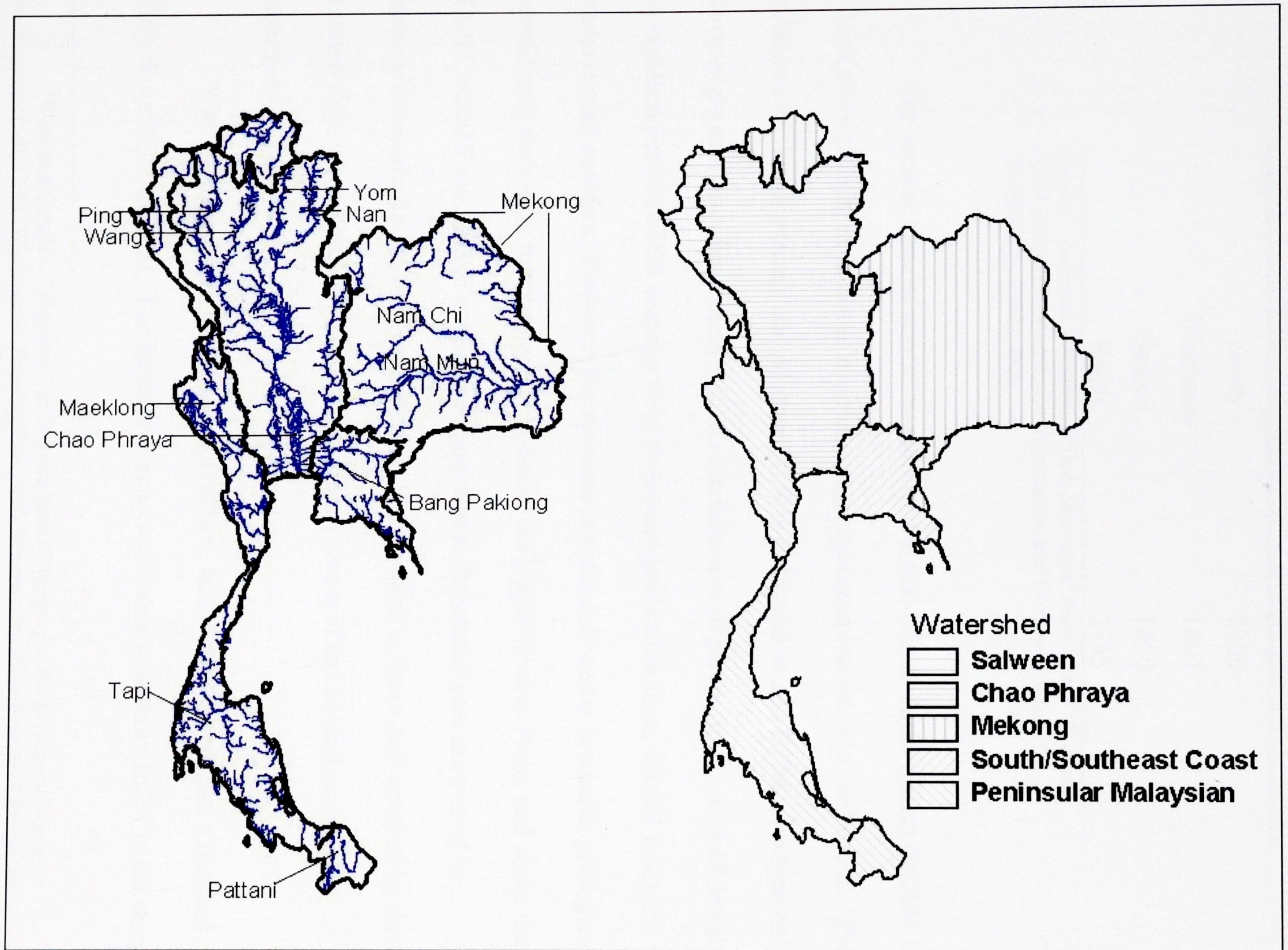


Figure 3. Major Rivers and Watersheds
Source: Marc Souris, Institut de Recherche pour le Developpement, 2005.

Table 2. Average Annual Rainfall by Region in 2002 (mm)

| | |
|---|---|
| North | 1360 |
| Northeast | 1607 |
| Central | 1650 |
| South | 2745 |

*Source:* National Statistical Office, *Statistical Yearbook of Thailand 2003* (Bangkok: Ministry of Information and Communication Technology, 2002), 482.

The total volume of rainfall is estimated at 800 billion cubic meters (BCM), of which about 600 BCM is lost to evaporation, evapotranspiration, and infiltration. The balance constitutes average annual runoff that is estimated at 200 BCM, of which only thirty-eight million cubic meters (MCM) can be stored in reservoirs.[28] An additional 12.5 to eighteen percent of the seepage from rivers and infiltration from rainfall reaches underground aquifers. However, the estimate is valid only under favorable geological conditions, such as in the Northern Highlands, the Upper Central Plain, and along the Gulf Coastal Plain. In the northeast region, where the central part is covered by impervious shale, and in the Lower Central Plain, which is about half covered by thick marine clay, it is estimated that only five to six percent of the rainfall reaches the aquifers.[29]

Water for domestic, industrial, agricultural, and other uses created a demand of fifty-three BCM in 2000. The demand is expected to rise to seventy BCM in the next ten

[28]Watchara Suiadee, "Thailand," in *OrganizationalChange for Participatory Irrigation Management*, ed. C. M. Wijayaratna, Report of the APO Seminar on Organizational Change for Participatory Irrigation Management, Philippines, 23 – 27 October 2000 (Tokyo: The Asian Productivity Organization, 2002), 292. (Accessed online February 26, 2003). Available: http://www.apo-tokyo.org/00e-books/AG-13_IrrigMgt.htm

[29]Ibid., 294.

years.[30] The expected deficit has been attributed to poor governmental policy, while rapid rural development; industrialization; promotion of tourism; and deteriorating water quality owing to excessive use of fertilizer and pesticides, urban sewage, and other contaminants all undermine efforts to alleviate the problems.

## Soils

The themes discussed above-geology, landform, climate, and hydrology-all contribute to pedogensis. The generally accepted factors of soil formation, the interaction of parent material, climate, topography, organisms, and time, are discussed in the Appendix. Nine soil orders, based upon the United States Department of Agriculture (USDA) Soil Taxonomic System[31] have been identified in Thailand (Table 3) and have been further categorized in twenty-nine sub-orders, and approximately 300 soil series.[32] In addition, the Thai pedon database contains information for about 1000 pedons.[33]

The tropics is the only region where all eleven of the soil orders identified by the USDA Soil Survey Staff occur.[34] Given this immense diversity, it is not too surprising that a relatively small country like Thailand contains nine of the eleven orders. Soils in Thailand range from relatively recent alluvial deposits, which are of medium to high

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[30]Ibid., 292.

[31]Kuneepong, "FAO Gateway to Land and Water Information."

[32]Ibid.

[33]Moncharoen et al., "Land Resource Constraints for Sustainable Agriculture in Thailand," 181.

[34]H. Eswaran, J. Kimble, T. Cook, and F. H. Binroth, "Soil Diversity in the Tropics: Implications for Agricultural Development," in *Myths and Science of Soils of the Tropics,* SSSA Special Publication Number 29, eds. Lal, R., and P. A. Sanchez (Madison, Wisconsin: Soil Science Society of America and American Society of Agronomy, 1992), 8.

fertility in the Central Plains and Gulf Coastal Plain, to mature Ultisols, which spatially dominate the kingdom.

Table 3. USDA Soil Orders in Thailand

| Soil Order | Percent of Total Land Area |
|---|---|
| Ultisols | 42.13 |
| Entisols | 33.75 |
| Alfisols | 9.16 |
| Inceptisols | 9.4 |
| Mollisols | 1.17 |
| Vertisols | 0.81 |
| Histosols | 0.14 |
| Spodosols | 0.12 |
| Oxisols | 0.03 |

*Source*: Kuneepong, "Thailand," 12.

Most major soil-forming parent materials are low in weatherable minerals, likely leading to micronutrient deficiencies.[35] Limestone ridges in the north, west, and south of the kingdom contribute little to the surrounding soils, being more resistant to weathering and composed mostly of calcium carbonate.[36] Northern upland soils are derived largely from granites, gneiss, shale, limestone, and sandstones-their fertility varying with parent material and type of clay minerals.[37]

[35]Yongyuth Osotsapar, "Micronutrients in Crop Production in Thailand," Taipei, Taiwan: Food and Fertilizer Technology Center, 1999 (Accessed online January 20, 2005). Available: http://www.fftc.agnet.org

[36]Stewart-Cox, *Wild Thailand*, 20.

[37]Phaikaew and Shelton, FAO Forage Resource Profile: Thailand.

Southern soils are derived from parent materials, such as limestone, bedded sediments, and granites, and vary from clay loam to sandy loam.[38] Most of the soils in this region are infertile, owing to high rainfall that induces rapid weathering and the leaching of parent materials. The soils typically lack major nutrients: nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), and sulfur (S). They similarly lack the micronutrients zinc (Zn) and copper (Cu).[39]

Soils in the northeast form one of the most extensive soil groups, and at the same time one of the most infertile soil groups in the kingdom.[40] In general, the soils are highly weathered, rarely possessing organic-matter content above one percent, and are usually considered to be irreclaimable.[41] Nearly all of the soils in the region are derived from sandstone, shale, or siltstone, which are high in quartz, and were already highly weathered when they were deposited. The soils are inherently low in nutrients, such as calcium (Ca), K, Mg, and P.[42] Low inherent fertility, combined with low moisture holding capacity; sandy surface horizon; low clay (less than six percent) and organic carbon content (approximately 0.4 percent), means that the soils have an extremely low

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[38]Ibid.

[39]Ibid.

[40]Jonathan D. Rigg, "The Role of the Environment in Limiting the Adoption of New Rice Technology in Northeastern Thailand." *Transactions of the Institute of British Geographers,* n.s., 10 (1985): 483 - 484.

[41]Parnwell, "Rural Poverty, Development and the Environment," 202.

[42]A.G., O'Donnell, J.K. Syers, P. Vichiensanth, P. Vityakon, M. A. Adey, P. Nannipieri, W. Sriboonlue, and A. Suwanarit, "Improving the Agricultural Productivity of the Soils of Northeast Thailand Through Soil Organic Matter Management," in *Soil Science and Sustainable Land Management in the Tropics*, eds. J.K., Syers and D.L. Rimmer (London: Cambridge University Press, 1994), 194.

cation exchange capacity (CEC) and are poorly buffered against changes in pH.[43] The majority of the northeastern soils are Ultisols. Their areal extent accounts for about forty-two percent of all soils in Thailand (Table 3).

Studies of legume crops in farmers' fields in Thailand have shown that many soil types suffer from one or more deficiencies of the micronutrients boron (B), iron (Fe), molybdenum (Mo), Cu, and Zn.[44] These nutrient deficiencies undoubtedly reflect an unbalanced soil chemistry, resulting in low fertility and diminishing crop yields.

The Thai Land Development Department has mapped soil fertility based upon the general soils map of Thailand using the USDA standard analysis of soil fertility (Figure 4). In general, most soils in Thailand have low fertility, in part owing to low nutrient parent materials and tropical climate, but also owing to heavy leaching and erosion as a result of the removal of native vegetation.

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[43]J.S. Watson, "Soil Organic Matter Management in Thailand," in *Soil Science and Sustainable Land Management in the Tropics*, eds. J.K. Syers and D.L. Rimmer (London: Cambridge University Press, 1994), 206.

[44]Osotsapar, "Micronutrients in Crop Production in Thailand."

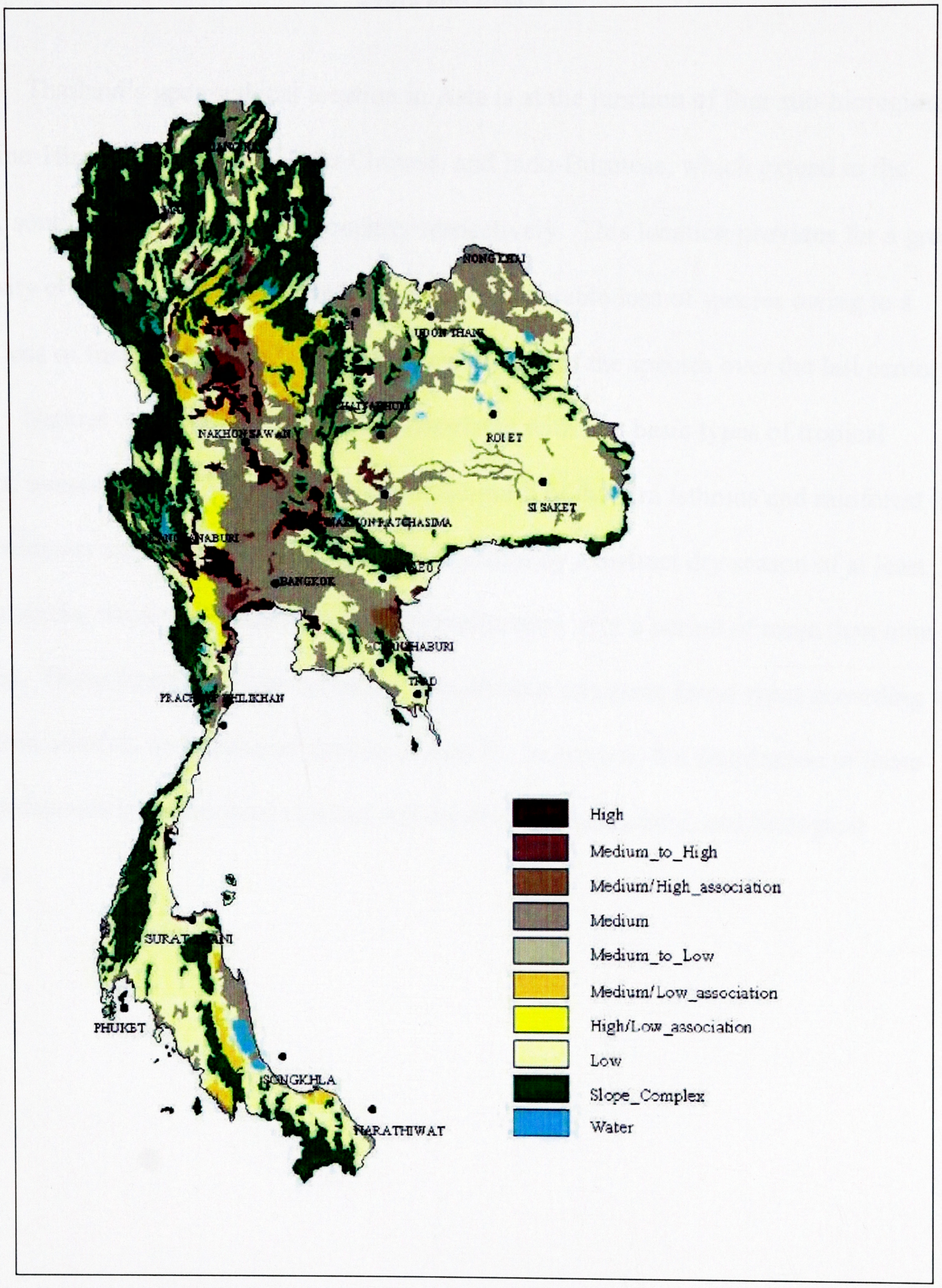


Figure 4. Soil Fertility
*Source*: Land Development Department Bangkok, 2000.

## Flora and Fauna

Thailand's geographical location in Asia is at the junction of four sub-bioregions: the Sino-Himalayan, Sundiac, Indo-Chinese, and Indo-Burmese, which extend to the north, south, east, and west of the country respectively. This location provides for a great diversity of species, although there has been a considerable loss of species owing to a rapid loss of forest habitat and the human exploitation of the species over the last century.

Natural vegetation in Thailand is associated with two basic types of tropical forests, monsoon forest in continental Thailand north of the Kra Isthmus and rainforest in the peninsular area. Monsoon forest is characterized by a distinct dry season of at least three months, while the rainforest receives precipitation over a period of more than nine months. These forest types can be further sub-divided into main forest types according to elevation, rainfall, and dominant species (Table 4). In general, the distribution of these forests depends upon the local climate, soil conditions, topography, and biological factors.

Table 4. Main Forest Types

| Main Forest Types | Elevation Range (m) | Rainfall (mm) | Dominant Species |
|---|---|---|---|
| Tropical Rain Forest | 0 - 600 | >2500 | *Dipterocarpus spp., Hopea spp., Shorea spp.Anisoptera spp., palms, rattans, abamboos* |
| Hill Evergreen Forest | >1000 | 1500 – 2000 | *Alstonia scholaris, Tetrameles nudiflora* |
| Dry Evergreen Forest | 0 – 500 | 1000 – 2000 | *Dipterocarpus turbinatus, D. costatus, D. alatus, Anisoptera costatus, Hopea odorata* |
| Pine Forest | 800 – 1800 | >1200 | *Pinus kesiya, P. merkusii* |
| Montane Evergreen Forest | 1000 – 1800 | - | *Fagaceae, Lauraceae, Magnoliaceae, Aceraceae, Theaceae, Oleaceae.* |
| Montane Evergreen Forest | 1800 – 2000 | - | *Fagaceae, Rosaceae, Lauraceae, Myrtaceae, Proteaceae, Theaceae* |
| Mixed Deciduous | 50 – 600 | <1000 | *Afzelia xylocarpa, Xylia xylocarpa, Tectona grandis, Lagerstroemia spp* |
| Dry Dipterocarp | <600 | <1200 | *Eipterocarpus obtusifolius, D. tuberculatus, Shorea siamensis, S. roxburghii* |
| Mangrove Forest | Coastlines-River estuaries | >2000 | *Rhizophora apiculata, R. macronata, Soneratia spp., Bruguiera spp.* |

*Sources:* Rachun Pooma and Anders Barfod, "Vegetation Types of Northern Thailand," in *Forest in Culture – Culture in Forest: Perspectives from Northern Thailand,* eds. Ebbe Poulsen et al. (Tjele, Denmark: Danish Institute of Agricultural Sciences, 2001), 12 – 14. Stewart-Cox, *Wild Thailand,* 22 – 24, 28.

According to the World Resources Institute (WRI),[45] the kingdom harbors 11,625 higher plant species[46] (seventy-eight threatened[47]), 265 mammals (thirty-seven

[45]WRI, "Earth Trends Country Profiles: Biodiversity and Protected Areas – Thailand," (Washington, D.C.: World Resources Institute, 2003): 1 – 2 (Accessed online March 15, 2005). Available: http://earthtrends.wri.org/pdf_library/country_profiles/bio_cou_764.pdf

[46]The number of known plants include vascular plant species (flowering plants, conifers, cycads and fern species), but do not include mosses. Known mammals exclude marine mammals. Known birds include only birds that breed in that country, not those that migrate or winter there. The number of known fish includes both freshwater and marine species. Ibid., 5.

threatened), 285 breeding birds (thirty-seven threatened), 338 reptiles (eighteen threatened), 308 fish (twenty-two threatened), and 103 amphibians. The flora and fauna of Peninsular Thailand have close affiliations to those of Peninsular Malaysia, while continental Thailand shares affinities with the Indo-Chinese and Indo-Burmese regions. About three percent of Thai faunal species are endemics which include seventy freshwater fish, fifty saltwater fish, thirty-one reptiles, thirteen amphibians, eight mammals and two bird species.[48]

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[47]The Number of threatened species includes all full species categorized at the global level as critically endangered, endangered, or vulnerable. Subspecies, introduced species, species whose status is insufficiently known, and species whose status has not been assessed are excluded. Ibid.

[48]Stewart-Cox, *Wild Thailand,* 29.

# CHAPTER 3

# CULTURAL – HISTORICAL CONTEXT

## Prehistoric Southeast Asian Environment

In 1952, Carl Sauer postulated that the origins of agriculture might well lie in Southeast Asia, challenging a long held belief of Neolithic origins in the Near East. Sauer argued that no other region was better suited, physically and biologically, for plant and animal domestication. Sauer believed that the agricultural arts were first developed in the Mesolithic, mid-way between the Palaeolithic and Neolithic periods.[49] Sauer's hypothesis inspired new research in the region, much of it focusing upon Thailand, where hundreds of archaeological sites have been identified.

A number of findings in Southeast Asia-including ancient plant remains, indirect evidence of early cultivation, and traces of Mesolithic field systems-came as a great surprise to many researchers.[50] Despite efforts to systematically collect data relating to the prehistoric evidence, some anthropologists admit that they are still data-deficient when it comes to developing inductive and realistic models of variable and changing human-environmental relationships.[51] Research in Thailand has revealed a mosaic of

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[49]Carl O. Sauer, "Planters of the Old World and their Household Animals," in *Prehistoric Agriculture*, ed. Stuart Struever (New York: The Natural History Press, 1971), 407, 411.

[50]Karl L. Hutterer, "Ecology and Evolution of Agriculture in Southeast Asia," in *An Introduction to Human Ecology on Agricultural Systems in Southeast Asia*, eds. A. Terry Rambo and Percy E. Sajise (Los Banos, Philippines: The University of the Philippines at Los Banos, 1984), 75.

[51]Lisa Kealhofer, "Human-Environmental Relationships in Prehistory: An Introduction to Current Research in South and Southeast Asia," *Asian Perspectives* 35 (1996): 114.

shifting patterns and changing characteristics over time and space, not fitting any generally accepted model or pattern. Penny et al. and Lisa Kealhofer[52] investigated sites in Thailand, and have demonstrated "that human environmental relationships reflect a high degree of complexity, nonlinearity, and cyclical variability, and not a linear evolution of agricultural systems."[53] Nevertheless, inquiries into the origins of agriculture in Southeast Asia have revealed information relative to prehistoric climate change, flora and fauna, and human impacts upon environmental systems, which is the concern of this current discussion. A review of this literature provides an important perspective regarding the physical environment and human impacts upon it through time.

Several climatic changes occurring during the Pleistocene succession of glacial and interglacial periods has greatly influenced contemporary Southeast Asian flora and fauna. During the Middle and Late Pleistocene, sea level lowering between fifty and 150 meters could have occurred several times, allowing faunal exchanges from continental Southeast Asia to the Indonesian archipelago. Christelle Tougard believes that faunal exchanges probably took place several times during glacial advance over the land bridge known as Sundaland when sea levels were low.[54] In modern bathymetric measurement, a

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[52]Ibid.

[53]Ibid.

[54]Christelle Tougard, "Biogeography and Migration Routes of Large Mammal Faunas in Southeast Asia during the Late Middle Pleistocene: focus on the Fossil and Extant Faunas from Thailand," *Palaeogeography, Palaeoclimatology, Palaeoecology* 168 (2001): 348.

sea level lowering of fifty meters would be sufficient to expose Sundaland, connecting Sumatra, Java, and Borneo with the Asian mainland.[55]

Climatic perturbations during this time established the present boarder between the Indochinese and Sundaic biogeographical provinces located at the Kra Isthmus, in peninsular Thailand (14° North on the Burmese side and 11° North on the Thai side). The northern Indochinese province includes South China, Burma, Thailand (North of the Kra Isthmus), Laos, Vietnam, and Cambodia. The southern Sundaic province includes the southern part of Thailand, Malaysia, Sumatra, Java, and Borneo.[56] The differences between these provinces include a stronger seasonality in climate and lower rainfall in the north. This is especially significant for flora, as it forms the boundary between the rain forest and monsoon forest, and is also significant for the distribution of insects, amphibians, birds, and mammals.[57]

Palaeoclimatic and palaeoecological studies in Southeast Asia reveal an environment during the Late Middle Pleistocene not very different from today.[58] Climatically, conditions were characterized by vegetation zones that were at lower altitudes than today, and slightly lower temperatures and humidity.[59]

Kealhofer and D. Penny provide the longest continuous sequence of vegetation and environmental change for continental Southeast Asia, through the pollen and

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[55]Ibid., 341.

[56]Ibid., 338.

[57]Ibid., 339.

[58]Ibid., 341.

[59]Christelle Tougard, Jean-Jacques Jaeger, Yaowalak Chimanee, Varavudh Suteethorn, and Somchai Triamwwichanon, "Discovery of a Homo sp. Tooth Associated with a Mammalian Cave Fauna of Late Middle Pleistocene Age, Northern Thailand," *Journal of Human Evolution* 35 (1998): 53.

phytolits record extracted from Nong Han Kumphawapi Lake in north-northeast Thailand.[60] Their analysis reveals several shifts occurring in arboreal and grass taxa, suggesting fluctuations in both rainfall and temperature during the Late Pleistocene. Kealhofer believes that the presence of Chloridoid grasses, concurrent with a scarcity of arboreal types, indicated an arid period at this time.[61]

Early Holocene grass taxa fluctuations continued with an increase in Bambusoid grasses, concomitant with temporary declines in both arboreal and Panicoid phytoliths, suggesting disturbance through burning. The researchers suspect that this may be of anthropogenic origin, as no evidence of comparable vegetational or climatic fluctuations are found in adjacent regions.[62] This period was followed by an increased diversity of Bambusoid grasses and diversification of arboreal taxa, indicating a more forested environment. This assemblage suggests relatively open dryland vegetation, incorporating open woodlands and dry, mixed deciduous forest.[63]

During the Middle Holocene, pollen data showed significant changes in local flora, with dramatic increases in sedges and fern spores, such as those in the modern herbaceous swamp site. The increases suggest a change in the hydrological regime, including a stronger wet season or a decline in seasonality. The Late Holocene data revealed further development of herbaceous swamp taxa, with a decline of swamp and dry land arboreal taxa, some significantly reduced or disappearing from the record. The authors note that this is suggestive of intensified anthropogenic activities, but did not fit

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[60]Lisa Kealhofer and D. Penny, "A Combined Pollen and Phytolith Record for Fourteen Thousand Years of Vegetation Change in Northeast Thailand," *Review of Palaeobotany and Palynology* 103 (1998): 83.

[61]Ibid., 88.

[62]Ibid., 89.

[63]Ibid.

with a slash and burn subsistence regime in which they would expect a more diverse set of burned species.[64]

About this same time (1998), the first and oldest fossil human remains in Thailand were found at Thum Wiman Nakin Cave,[65] about 180 kilometers southwest of Nong Han Kumphawapi. The specimen, a tooth identified as *Homo* sp., is believed to date to the Late Middle Pleistocene.[66] The tooth was recovered among 1500 mammalian remains composed of small rodents, bats, carnivores, ungulates, proboscideans, and primates-including five species now absent from Thailand.

No trace of human activity could be identified at the cave, and given the large accumulation of mammalian remains, the researchers have attributed its use to carnivores (probably hyaenas) rather than human.[67] Tougard et al. acknowledge a number of other significant discoveries of human remains during the Quaternary in China, Java, Lampang Province (North Thailand), and Southwest Thailand.[68] It is interesting to note that the dates of these discoveries, as well as increasing evidence of human activity, concur with Carl Sauer's hypothesis of agricultural origins in Southeast Asia during the Mesolithic.

A study by Chester Gorman identifies common traits among Mesolithic remains in Southeast Asia. Based upon the remains and radiocarbon chronology, Gorman has suggested an early "techno-complex," first appearing during the late Pleistocene and

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[64]Ibid., 89 – 90.

[65]Tougard, et al., "Discovery of a *Homo sp.* Tooth,": 47.

[66]Ibid.

[67]Ibid., 53.

[68]Ibid., 52.

continuing as a recognizable complex until ca. 5000 to 6500 B.C.[69] The author believes that these traits reflect a widely diffuse and common, human-ecological adaptation to the Southeast Asian environment, revealing patterns of hunting, fishing, and collecting, leading to a shift in patterns associated with the emergence of early village agriculture on the plains.[70]

Gorman defines two distinct techno-cultures during the Mesolithic Period as krast-riverine and coastal, indicating either a seasonal shift in exploitative habits by a single population, or different populations adapted to particular niches existing at the same time.[71] While the available evidence was incomplete, extrapolation of vegetational studies and known eustatic variations in sea level supports a theory of seasonal shifts. Gorman believes that the largest area of optimal environment (tropical deciduous woodlands and mixed savanna) available to sustain early populations was inundated by rising sea levels at the end of the Pleistocene. He believes that lower sea levels from about 23,000 to around 12,000 B.P. resulted in the expansion of the continental land mass to almost twice its present size. From about 12,000 to around 5000 B.P., Southeast Asia experienced a climatic amelioration ending with temperatures 2 to 3°C above the present range, and sea levels about two meters above present levels. From this, Gorman postulates that about 15,000 years ago, Mesolithic populations occupied highland areas as intermediately optimal environments, as apposed to coastal areas.[72]

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[69]Chester Gorman, "The Hoabinhian and After: Subsistence Patterns in Southeast Asia during the Late Pleistocene and Early Recent Periods," *World Archaeology* 2 (1971): 300.

[70]Gorman tentatively sets the known dates of evidence from approximately 12,000 to 8500 B.C., pending completion of radiocarbon analysis.

[71]Ibid., 301.

[72]Gorman, "The Hoabinhian and After": 306.

Gorman's reconstruction of human exploitative patterns is largely based upon radiocarbon data that he believes to be the most detailed chronology yet available for the region. The data is that from the Spirit Cave in Northwestern Thailand, fist excavated by Gorman in 1966.[73] Initial occupation of the cave has been estimated to be about 13,000 to 14,000 B.P., and terminating about 7600 B.P. The site is characteristic of fifteen other inland sites associated with upland karstic formations near small streams, or others in sub-montane areas near streams. Gorman believes that these krast-riverine sites are characteristic of Indochina and Malaya, indicating a widespread pattern over mainland Southeast Asia.[74]

With the exception of botanical remains, Spirit Cave shares evidence of exploited faunal remains with many other inland sites. Several species of pig, deer, bovines, primates, and freshwater aquatic fauna being the most commonly exploited. Pig and deer species are common at ten sites, bovines at six sites, and primates at seven sites. A number of smaller mammalian species and large carnivore species appeared common among four sites. Freshwater fauna including snails, mollusk, fish and crustacean are reported at nine sites, with marine mollusks appearing at several. The marine species are often perforated or ground, and given their considerable distance from the sea, indicates a significance beyond dietary value.[75]

Botanical remains identified at Spirit Cave (ca. 10,000 – 6000 B.C.) indicate exploitation of tree crops, vegetables, and narcotics. Types of plant remains identified include almond, betel, broadbean, pea, bottle gourd, Chinese water chestnut, pepper,

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[73]Hutterer, "Ecology and Evolution of Agriculture in Southeast Asia," 88.

[74]Gorman, "The Hoabinhian and After," 305.

[75]Ibid., 308 – 310.

butternut, candle nut, and a type of cucumber. Gorman believes that the presence of the bottle gourd, Chinese water chestnut, cucumber, and legumes, suggest a stage of plant exploitation beyond simple gathering. While no evidence exists to support this claim, the remains indicate a sophisticated use of selective species, which are still culturally important in Southeast Asia.[76]

Gorman also mentions five coastal sites-two in Vietnam, one in Thailand, one in Malay, and one on the northeast coast of Sumatra-describing a pattern of marine orientation and exploitation which could have existed over most of Southeast Asia contemporaneously with inland occupation. The scarcity of coastal sites may be attributed to the periodic submergence of the Sunda Shelf, as contemporary sea levels are up to seventy-two meters higher than those of the Late Pleistocene. Of the three sites considered, the primary exploitation is of marine biota-however all three sites contain the remains of terrestrial faunal common to the inland sites, suggesting concurrent existence.[77]

Only three termination dates are available for sites during the Mesolithic Period considered by Gorman. The dates broadly range from about 7300 to 4400 B.P. Two dates for early lowland agricultural activities are believed to be from about 5500 to 3700 B.P. From these dates and other radiocarbon determinations, Gorman establishes the Pleistocene-Holocene boundary for Southeast Asia at roughly 8000 B.C. Inferring from these dates, temporal parameters of Mesolithic orientations are visible during the Late Pleistocene, and continue, with modifications, until about 3500 to 3000 B.C. About this

[76]Ibid., 310 – 311.

[77]Ibid., 306, 310, and 316.

time, emergence of early village farming on the plains of Southeast Asia is well documented, showing continuous occupancy through to the historical period. Considering the time period from 12,000 to 2000 B.C. then, the period witnessed a shift from upland to lowland settlement, and a concurrent shift from subsistence hunting and gathering to early cereal agriculture.[78]

According to The International Council on Monuments and Sites (ICOMOS), Nok Nok Tha, and later Ban Chiang, on the Khorat Plateau in northeast Thailand, exhibit independent and vigorous cultural development during the fourth millennium B.C., "which shaped contemporary social and cultural evolution over much of Southeast Asia …and into the Indonesian archipelago."[79]

Ban Chiang archaeological site is an example of a cultural landscape changing over time, developing, and ultimately reaching an end. With the introduction of a different culture, a new landscape was superimposed upon its remnants.[80] The site is believed to have been occupied around 3600 B.C. and lasting until about ca. 1000 B.C. The prehistoric settlement lies beneath the modern village of Ban Chiang, established by Loatian refugees in the late eighteenth century.[81]

The site is evident of an early hunter-gatherer economy that was beginning to develop sedentary farming with domesticated fauna, and an early form of dry rice

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[78]Ibid., 303, 305.

[79]ICOMOS, "Advisory Body Evaluation: Ban Chiang Archaeological Site, Province of Udon Thani, Thailand," World Heritage List No. 575 (1992): 1 – 4 (Accessed online March 10, 2005). Available: http://whc.unesco.org/pg.cfm?cid=168

[80]Carl O. Sauer, "The Agency of Man on the Earth," in *Readings in Cultural Geography*, eds. Philip L. Wagner and Marvin W. Mikesell (Chicago: The University of Chicago Press, 1962), 309 – 310.

[81]ICOMOS, "Advisory Body Evaluation: Ban Chiang."

cultivation. The period from about 1000 to 300 B.C. is notable for the introduction of wet rice farming, and pottery.[82] Archaeologists have established evidence that bronze implements were forged in the area as early as 3000 B.C. and not introduced from outside. They support their claim by pointing out that both copper and tin deposits (components of bronze) are found in close proximity to Ban Chiang. If the archaeologist's claims are correct, Thai bronze forgers would have predated the "Bronze Age," which is traditionally believed to have begun in the Middle East around 2800 B.C.[83]

In the first millennium A.D., mainland Southeast Asia's first Indianized realms appear, but then in a span of a few centuries their Mon, Khmer, and Cham peoples decline. In their place, the Burmese, Tai, and Vietnamese states arise and come to dominate the second millennium.[84] On a case by case basis, these shifts appear to be ethnic and political successions, but taken together in a regional context, the similarities suggest an agricultural change where upland valley complexes (Burmese, Thai, and Vietnamese) subordinate earlier lowland agricultures (Mon, Khmer, and Cham).[85]

Richard O'Connor explains that while the former group employed weirs to tap perennial streams and rivers, thereby diverting water into fields and canals, the latter group practiced a variety of flood management schemes in rain-fed agricultural

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[82]Ibid.

[83]Barbra Leitch LePoer, ed., *Thailand: A Country Study*, 6th ed. Library of Congress, Federal Research Division, Area Handbook Series (Washington, D.C.: Government Printing Office, 1989), 5.

[84]Richard A. O'Connor, "Agricultural Change and Ethnic Succession in Southeast Asian States: A Case for Regional Anthropology," *The Journal of Asian Studies* 54 (1995): 968.

[85]Ibid.

systems.[86] O'Connor believes that the first upland complex appeared along the Red River in Vietnam, then in Burma, and finally in Thailand. Sometime during the first millennium A.D., the Thai complex appeared on the edge of the hills, and made inroads into the lowlands where it met flood farming and was highly successful. The Thai were able to exploit niches above and below the flood farmers. The foothills above were naturally favored, while below in the floodplains the Thai could breach levees to drain and irrigate back swamps. The levees and floodplain features were new to the Thai, but manipulating water flows and draining swamps were not.[87]

The Thai upland-lowland meeting is presumed to have resulted in an assimilation of agricultural complexes, rather than one population physically displacing another.[88] "Elsewhere this upland-lowland meeting had more dramatic consequences, and it seems possible that the shape of Vietnamese culture and Burmese agriculture crystallized out of this encounter."[89] Once the Thai, Vietnamese, and Burmese established footholds, they succeeded by politics as much as by agriculture.

Various peoples continued migrating into the region for centuries, and in 1238 a Thai chieftain declared independence from the Khmer and established a kingdom at Sukhothai-at the center of modern Thailand. Sukhothai was succeeded in the fourteenth century by the kingdom of Ayutthaya, only to be invaded and destroyed by the Burmese in 1767. The Burmese were soon expelled and the kingdom reunified under the Chakkri

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[86]Ibid., 969 – 970.

[87]Ibid., 980 – 981.

[88]Ibid., 970.

[89]Ibid., 981.

Dynasty, followed by decades of conscious nation building.[90] This new kingdom, known as Siam, was based upon its predecessors (Ayutthaya and Sukhothai), and was supported by wet-rice agriculture. Over the following century, trade with China and India was greatly expanded, and in 1855 the imposition of the Bowring Treaty by the British opened up the export of Thai rice to British colonial states, especially Singapore and Malaya.[91]

During the nineteenth century a world market demand for rice accelerated agricultural production, where cooperation and indigenous irrigation skills hardly mattered, as the market blindly rewarded whomever had the most rice.[92] "Market forces thus completed an ethnic expansion and agricultural shift that had begun in mountain valleys at least two millennia earlier."[93]

In the late nineteenth and early twentieth centuries, colonial powers intensified patterns of resource exploitation in Southeast Asia. By the end of colonial rule, the regions economies were dependant upon export-oriented commercial resource extraction.[94] Large scale production of selected natural resources and plantation crops exploited land resources and environmental conditions-Malaya with tin, palm oil, and

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[90]LePoer, *Thailand,* xxi – 3.

[91]Ibid.

[92]O'Connor, "Agricultural Change and Ethnic Succession," 984.

[93]Ibid.

[94]Raymond L. Bryant and Michael J.G. Parnwell, "Politics, Sustainable Development and Environmental Change in Southeast Asia," in *Environmental Change in Southeast Asia: People, Politics and Sustainable Development*, eds. Michael J. G. Parnwell and Raymond L. Bryant, Global Environmental Change Series III (London: Routledge, 1996), 4.

rubber; Java with coffee and sugar; the Philippines with sugar, abaca, and coconuts; Burma and Thailand with rice, teak, and minerals.[95]

Accompanying extensive agricultural expansion was the rapid depletion of the regions forests. Prior to 1850, most of Southeast Asia was covered in forest, but by the late 1980s, Vietnam, the Philippines, and Cambodia had lost eighty, seventy-nine, and seventy-six percent of their original wildlife habitat respectively. Other Southeast Asian countries sustained similar losses: Thailand seventy-four percent; Burma and Laos seventy-one percent; and Malaysia forty-one percent.[96] The impact of human activity upon environmental systems in the region has been detrimental and on-going:

> Environmental degradation in the region is pervasive, accelerating, and unabated. At risk are people's health and livelihoods, the survival of species, and ecosystem services that are the basis for long-term economic development. Economic development and poverty reduction efforts are increasingly constrained by environmental concerns, including degradation of fisheries and forests, scarcity of freshwater, and poor human health as a result of air and water pollution. Intensified crop and livestock production combined with misdirected incentives have contributed to increased production of chemical and organic wastes (and accompanying health risks), natural resource and biodiversity loss, and soil erosion.[97]

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[95]Ibid., 5.

[96]IUCN/UNEP 1988 – 1989 data in Andrew Goudie, *The Human Impact*, 155.

[97]Asian Development Bank, *Asian Environmental Outlook 2001* (Manila: Asian Development Bank, 2001), 2.

The Kingdom of Thailand

The first mention of Thai peoples in the region is believed to be a twelfth-century A.D. inscription at the temple complex of Angkor Wat in Cambodia, referring to *syam*, "dark brown" people.[98] The Chakkri Dynasty, emerging during the eighteenth century was known as Siam until 1939, when a constitutional amendment designated a name change to Thailand. The romanization of Thailand, in Thai script is *Prathet Thai,* which is literally translated as "country free."[99] Thailand is the only Southeast Asian country that has never been colonized by a European power, a circumstance attributed to a series of Thai kings who reigned between 1857 and 1910.[100] The kings convinced the British and French imperialist powers that Siam should act as an independent buffer state, although in the late 1850s Siam was forced to cede territory to British Burma and Malaya on the west and south, and to French Indochina in Cambodia and Laos to the east. This annexation of Siamese territory delineates modern Thailand's political boarders.

Thailand covers an area of about 514,000 square kilometers ($km^2$), comprised of 511,770 $km^2$ land, and 2230 $km^2$ water. The kingdom lies between latitudes 5° 37' N and 20° 27' N and longitudes 97° 22' E to 105° 37' E in the heart of mainland Southeast Asia. Spanning roughly sixteen latitudinal degrees, Thailand is about 1650 km from north to south, and about 800 km from east to west at its widest part-from Three Pagodas Pass to the Mekong River in the east. At the Kra Isthmus in southern Thailand, its narrowest point, it is only eleven km wide. Thailand is bounded to the west–northwest

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[98]LePoer, *Thailand*, 3.

[99]Ibid.

[100]Rhoads Murphy, *A History of Asia* (New York: Harper Collins Publishers, 1992), 294, 334.

by Burma and to the east and northeast by Cambodia and Laos respectively. Peninsular Thailand is bounded in the west by the Andaman Sea, to the south by Malaysia, and to the east by the Gulf of Thailand (Figure 5).

## General Physiography

Thailand can be divided into four major regions that are roughly delineated by rivers and mountain ranges: the Northern Region; the Northeast Plateau; the Central Plain; and the Southern Peninsula. Each of the four geographical regions differs from the others in population, resources, natural features, and social and economic conditions. The most prominent topographic features are high mountains, a central plain, and an upland plateau.[101]

Mountains cover much of northern Thailand and extend along the borders of Laos and Burma, reaching south to about 18°N. The north-south oriented mountains are parallel from west to east, all reaching over 2000 meters above sea level (masl), particularly those near Chiang Mai, Chiang Rai, Lampang, and Nan provinces. Doi Inthanon is the highest point above mean sea level in Thailand at about 2565 meters in Chiang Mai Province. The region is the source of several major Thai rivers, including the Nan, Wang, and Yom, whose confluence forms the Mae Nam Chao Phraya in the central region just south of 16°N.

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[101]LePoer, *Thailand,* 60 – 61.

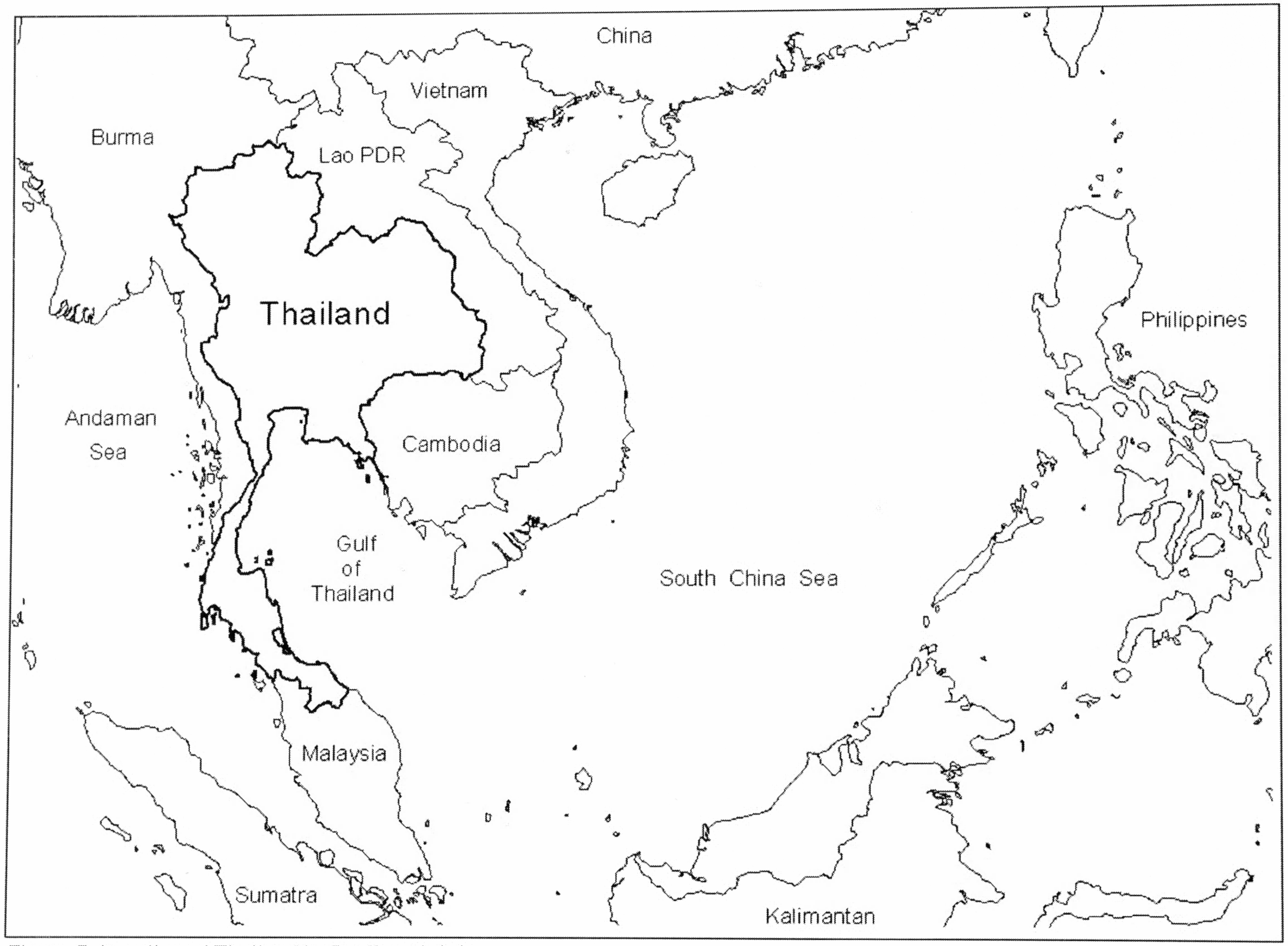

Figure 5. Location of Thailand in Southeast Asia

The northern region occupies about seventeen million hectares (politically), and can generally be divided into three altitudinal floristic zones: the lowlands, the uplands, and the highlands. The lowlands occupy about fifteen percent of the area, and range from less than 200 masl to 500 masl. They are relatively flat with fertile alluvial basins. This area produces paddy rice, intercropped with tobacco, soybeans, garlic, peanuts, and vegetables.[102] The uplands occupy about forty-five percent of the area. They are undulating to hilly to about 500 masl. The principal crops are upland rice, maize, and grain legumes.[103] The highlands occupy about forty percent of the northern region, ranging from 500 to 2500 masl. Mixed deciduous, dry deciduous dipterocarp, and evergreen forests extend from about 600 to 2200 masl.[104] In the 1970s and 1980s, governmental development projects targeted swidden cultivators in an effort to reduce forest destruction and curb opium production. Among their strategies were crop substitution schemes, which ultimately exacerbated forest loss by extensive expansion to accommodate high value monocrops for export.[105]

Central Thailand consists of a large low level alluvial plain traversed by the Chao Phraya River. The Chao Phraya is the kingdom's principal river. It feeds into the delta at Nakhon Sawan Province north of Bangkok, and exists into the Gulf of Thailand. Owing to the fertility of the Mae Nam's alluvial deposits in the Chao Phraya Delta, Thailand has

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[102]Vitoon Reunglertpanyakul, *Organic Agriculture and Rural Poverty Alleviation: Potential and Best Practices in Asia*, VII. National Study: Thailand (Bangkok: United Nations Economic and Social Commission for Asia and the Pacific [ESCAP], 2002), 177.

[103]Ibid.

[104]Rachun Pooma and Anders Barfod, "Vegetation Types of Northern Thailand," in *Forest in Culture – Culture in Forest: Perspectives from Northern Thailand,* eds. Ebbe Poulsen et al. (Tjele, Denmark: Danish Institute of Agricultural Sciences, 2001), 12 – 15.

[105]Anak Pattanavibool, Natural Resources Conservation Office, Royal Forest Department, Bangkok, personal communication, November 21, 2002.

been dubbed "The Rice Bowl of Asia." This region possesses the richest agricultural soils and is also the most densely populated region in the kingdom. A complex and extensive irrigation system in the delta, developed for wet rice agriculture, has provided economic support to sustain the development of the Thai State from the thirteenth century kingdom to the present. Bangkok is the capitol city of Thailand and is the major center for trade, transportation, and industrial activity. The city is situated on the southern edge of the central region near the Gulf of Thailand. Most districts of Bangkok are only three meters above sea level. Higher land above the delta is farmed, with maize, sorghum, soybean, cotton, bananas, cassava, sugar cane, and fruit being the principal crops. Almost the entire natural environment in and around the Chao Phraya Plain has been cleared for agriculture and settlements. Rice paddies have replaced freshwater swamp and monsoon forest, and wetlands have been drained and severely disturbed.[106]

In stark contrast to the Central Plain, the Western Forest Complex lies about 250 km northwest Bangkok, alongside the western international border with Burma. The area is the largest surviving forest tract in Thailand, and the largest conservation area in mainland Southeast Asia, covering 18,730 $km^2$. The area is comprised of nine national parks, six wildlife sanctuaries, and two proposed national parks. Two of the largest wildlife sanctuaries, Huai Kha khaeng and Thung Yai Naresuan, harbor tigers, elephants, gaurs, bantengs, and tapirs, among the 120 mammal species, and 400 bird, ninety-six reptile, forty-three amphibian, and 113 freshwater fish species. The protected areas are

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[106]Philip Round, Sompoad Srikosamatara, Nantiya Aggimarangsee, and Eric Wikramanayake, "Chao Phraya freshwater swamp forests," IM0107 (Accessed online April 18, 2005). Available: http://www.worldwildlife.org/science/ecoregions/indo_malayan.cfm

under threat from swidden cultivation, agricultural encroachment, wild fires, infrastructure development, mining, illegal logging, and the poaching of wildlife.[107]

Northeast Thailand is divided into the Sakon Nakhon and Korat Basins by the northwest-southeast oriented Phu Phan Ridge in the northeastern part of the region. The Mae Nam Mun and Lam Nam Chi, as well as other northeastern waterways exit into the South China Sea through the Mekong River, which delineates much of the north-northeastern and eastern plateau, as well as the international boarder with Laos. The elevation extremes in this region range from about 300 m to 100 masl in Ubon Ratchathani Province. This forms a high level plain in the west, while the smaller eastern plain inclines from west to east towards the Mekong River. The region is known locally as Isan, meaning prosperity and vastness-which is appropriate only as far as vastness is concerned. The region lags far behind the rest of the kingdom in terms of development, income, and natural resources.

Of Isan's total land area of seventeen million hectares, only fifty-nine percent consists of cultivable arable land, of which thirty-six percent is suitable for paddy and sixty-four percent for upland crops.[108] Nevertheless, rice is the staple crop, and paddy land covers 69.6 percent of the area classified as agricultural holdings.[109] Field crops and permanent crops comprise 16.7 and 2.7 percent respectively.[110] Other crops regularly

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[107]United Nations Environment Programme World Conservation Monitoring Centre, "Natural Site Datasheet: Thung Yai Naresuan Wildlife Sanctuary" (Accessed online March 15, 2005). Available: http://www.wcmc.org.uk/protected_areas/data/wh/thungyai.html

[108]Rigg, "The Role of the Environment," 483.

[109]National Statistical Office, Ministry of Information and Communication Technology, *2003 Agricultural Census* (Bangkok: 2003). Available: http://www.nso.go.th/eng/agriculture/agr_census2003.htm

[110]Ibid.

grown include maize, sugarcane, pineapple, cotton, sorghum, mung beans, soybeans, groundnuts, kenaf, tobacco, and various oilseeds.

The region has a large concentration of small reservoirs created by obstructing the surface flow of small streams. These small man-made impoundments are created for the purposes of irrigation, domestic water supply, fish and shellfish culture, and the harvesting of aquatic plants. In recent years, more water bodies have been created under the Village Fisheries Project to facilitate fish culture in order to improve food security for the rural poor.[111]

The distinguishing natural features of peninsular Thailand in the south are long coastlines, offshore islands, and mangrove swamps. Mountains along the northern and western boarders with Burma extend southward through this region to the Malay Peninsula. Phuket Ridge along the west coast and Nakhon Si Thammarat Ridge in the central lower south separate the region physically into east and west. The narrow peninsula is distinctive from the rest of the kingdom in climate, terrain, and resources. Most of the region has been devoted to agriculture at the expense of vast tracts of lowland forests. Of the percentage of land classified as agricultural holdings, fifty-seven percent is devoted to Para rubber, 27.4 percent to permanent crops, and about ten percent to rice. Other crops and economic pursuits include palm oil, pineapple, coconut, aquaculture, and fishing.[112]

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[111]Food And Agriculture Organization United Nations, *Fisheries Management of Small Water Bodies in Seven Countries in Africa, Asia and Latin America,* FAO circular no. 933 FIRI/C933 (Rome: 1997), 4.3 – 4.5.1. Available: http://www.fao.org/docrep/W7560E/W7560E00.htm

[112]National Statistical Office, Ministry of Information and Communication Technology, *2003 Agricultural Census,*. Bangkok: 2003. Tb1 Whole Kingdom, Tb5 Number and Area of Holdings by Land Use (Accessed online February 10, 2005). Available: http://www.nso.go.th

Thai Peoples and Economy

Thai statistics report a population of approximately 62.7 million people in 2002, comprised of seventy-five percent Thai and fourteen percent Chinese,[113] while the Malay, Khmer, Mons, and other ethnicities also dwell in twenty different provinces.[114] The population of Thailand is approximately seventy percent rural, with the greatest concentration of people in the central region. The Thai labor force by sector is fifty-six percent agricultural, fifteen percent industrial, and thirty-one percent in services.[115]

Major industries include tourism, textiles, and agricultural processing. Thailand is the world's second largest producer of tungsten and third largest producer of tin.[116] All non-fuel mineral resources identified in the kingdom, except for copper and potash, have been developed and produced both for export and domestic consumption, including barite, fluorite, gold, gypsum, iron ore, lead, quartz, zinc (economically the most important), antimony, ball clay, bentonite, diatomite, dolomite, feldspar, kaolin, limestone, manganese, marl, phosphate, rock salt, and silica sand.[117] The kingdom also

[113]National Statistical Office, *Population and Labor Statistics,* Excel Workbook Table 1.11 (Bangkok: Ministry of Information and Communication Technology, 2003) (Accessed online January 11, 2005). Available: http://www.nso.go.th

[114]Mikael Gravers, "Ethnic Minorities in Thailand: Figures and Selected Biography," in *Forest in Culture – Culture in Forest: Perspectives from Northern Thailand*, eds. Ebbe Poulsen et al. (Tjele, Denmark: Danish Institute of Agricultural Sciences, 2001), 18. Graver lists ten ethnic minorities in Thailand: Karen, Hmong, Lahu, Akha, Yao, H'Tin, Lisu, Lua, Khamu, and Mabree.

[115]National Statistical Office, *Population and Labor Statistics*, Table 1.19 (Bangkok: 2003)

[116]United States Central Intelligence Agency, The World Factbook 2003 (Accessed online March 1, 2004). Available: http://www.cia.gov/cia/publications/factbook

[117]John C. Wu, "The Mineral Industry of Thailand – 2002," in *Minerals Yearbook*, Vol. III – Area Reports: International, U.S. Geological Survey (Accessed online January 20, 2005). Available: http://minerals.usgs.gov/minerals/pubs/country/2002/thmyb02.pdf

has limited resources of mineral fuels, which include lignite, natural gas, and crude petroleum.[118]

Buddhism is the official state religion in Thailand, and is practiced by ninety-four percent of the population. It is followed by Islam at 4.5 percent, and a small percentage of Christians and tribal religions.[119] The kingdom has approximately 32,000 Buddhist monasteries,[120] 18,000 temples,[121] 460,000 monks,[122] and 140,000 Buddhist priests who practice predominately Theravadan Buddhism.[123]

A peaceful coup in 1932 led to a constitutional monarchy. A new Thai Constitution was ratified in 1997. Presently, His Majesty Bhumibol Adulyadej is the ninth king of the Chakri dynasty, and is the longest reigning king in Thai history, as well as the world's longest reigning living monarch. His Majesty ascended the throne in 1946 following the death of Rama VIII. The new Thai constitution of 1997 stipulates that the king be enthroned in a position of revered worship and not be exposed to any accusation or action. The majority of Thai citizens regard His Majesty as a deity, partly because of tradition, but also because of his involvement in public works and environmental problem-solving.

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[118]Ibid.

[119]LePoer, *Thailand*, 107 – 108.

[120]Joe Cummings and Steven Martin, *Thailand: What to do in the Land of Wats*, 9th ed. (Oakland: Lonely Planet Publications, 2001), 56.

[121]LePoer, *Thailand,* 104.

[122]Cummings and Martin, *Thailand*, 56.

[123]LePoer, *Thailand*, 96, 99.

## Nineteenth Century Agricultural Commercialization and Expansion

In the early nineteenth century, agricultural commercialization was centered around the central plain and near seacoasts that were accessible by existing transport. During this time, production was increased by expansion with more or less the same farming technology. After the Second World War, a large expansion of world trade in agricultural products encouraged massive expansion of farmland to accommodate several cash crops for export. The diverse indigenous crops that once provided subsistence were replaced in order to incorporate new crops, such as maize, kenaf, sugar cane, and cassava –crops introduced along with off-farm inputs to boost farm productivity under the banner of the Green Revolution.

Adopting Green Revolution technologies required the government to invest in irrigation projects and develop research and extension services for the modern farming system. These infrastructural projects required massive capital investment not available within the country, and most funds were obtained from the World Bank.[124] One of the requirements imposed by the World Bank was the development of mid-term national economic development plans. These plans are produced by the Office of the National Economic and Social Development Board, and are revised every five years. The plans are now known as National Economic and Social Development Plans. The objectives of the plans are to provide opportunities for participation by all Thai peoples to identify the direction and framework for national development.[125]

[124]United Nations Economic and Social Commission for Asia and the Pacific, *Organic Agriculture and Rural Poverty Alleviation: Potential and Best Practices in Asia,* Bangkok: 2001, 1 – 216 (Accessed online May 2, 2003). Available: http://www.unescap.org/rural/doc/OA/OA-Bgrd.htm

Through the introduction of the government's First National Economic and Social Development Plan (1961 – 1966), agricultural policy emphasized improving yields and productivity by adopting Green Revolution technologies. Its design was to play the duel role of providing foreign currencies needed to finance industrialization while providing inexpensive food for a rapidly growing urban and industrial population.[126] With the policy to keep agricultural prices low, farmers were left with little choice but to intensify production. This basic framework was employed in the agriculture sector until the early 1990s.[127]

In the late 1970s, agriculture production was integrated with factory processing and agribusiness management. Farmers were contracted to produce specified quality and quantity of crops for agro-processing businesses. Farmers were provided with credit, necessary farm inputs, technical advice, and subsistence loans to survive between harvests. This forced the farmers to sell at prices earlier agreed upon, many times at losses owing to market forces. The farmers' relationship with agribusiness, over time, has effectively turned many independent farmers into laborers in their own fields.[128]

Despite several subsequent agricultural policies that were designed to improve the well-being of small-scale farmers, none have been successful.[129] The adoption of Green

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[125]National Economic and Social Development Board, Office of the Prime Minister, *The Ninth National Economic and Social Development Plan (2002 – 2006)* (Bangkok, Thailand: 2001). Available: http://www.nesdb.go.th

[126]Walden Bello, Shea Cunningham, and Li Kheng Poh, *A Siamese Tragedy: Development and Disintegration in Modern Thailand* (London: Zed Books, 1998), 135.

[127]ESCAP, *Organic agriculture and rural poverty alleviation,* 175.

[128]Ibid., 176.

[129]Bello, et al., *A Siamese Tragedy,* 134.

Revolution technologies was supposed to improve the productivity of the agricultural sector. Instead, the experience has further exacerbated rural impoverishment and has had a tremendously negative impact upon rural natural resources, undermining the basic livelihood of rural farmers.[130]

Widespread commercialization of agriculture in Thailand has brought considerable changes in cultivated land area, type of crops sown, production techniques, farm income, and land tenure.[131] Economic incentives beginning in early 1980 established large commercial pulpwood plantations, and by 1992 approximately 800 $km^2$ had been planted in eucalyptus.[132] Local and foreign investors continued to lobby the Thai Government for tens of thousands of square kilometers for production, resulting in a program in 1991 to evict five million residents of National Reserve Forests in order to free approximately 14,700 $km^2$ for eucalyptus plantations.[133] Within a year, about 40,000 families had been forcibly displaced in the Northeast, the program being scrapped by the government only owing to a massive popular movement that overthrew the military junta.[134] In effect, the experience of commercial eucalyptus production in Thailand

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[130]Parnwell, "Rural Poverty, Development and the Environment," 207.

[131]John Girling, "Is Small-holder Cultivation Viable? A Question of Political Economy with Reference to Thailand," *Pacific Affairs* 59 (1986): 189.

[132]Larry Lohmann, "Freedom to Plant: Indonesia and Thailand in a Globalizing Pulp and Paper Industry," in *Environmental Change in Southeast Asia,* 36 – 37.

[133]Ibid., 41.

[134]Ibid.

increased deforestation[135] and displaced, impoverished, and denied the rights of tens of thousands of village families to a stable subsistence.[136]

In the mid-1980s, nearly sixty-nine percent of the labor force was engaged in the agricultural sector, dominated by independent smallholder farms, while nearly eighty percent of the population depended upon it for their livelihood.[137] The statistical trends quantified in Table 5 show that the contribution of agriculture to the kingdom's economy has declined since 1980, from about twenty-three percent to nine percent, while the industrial and services sectors have grown rapidly.

Table 5. Shares of Major Sectors in the 1980, 1990, and 2002 GDP (percent)

| | Agriculture | | | Industry | | | Services | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1990 | 2002 | 1980 | 1990 | 2002 | 1980 | 1990 | 2002 |
| GDP | 23.2 | 12.5 | 9.0 | 28.7 | 37.2 | 42.5 | 48.1 | 50.3 | 48.5 |

*Source:* Asian Development Bank, 2003

As one observer points out, the underlying dynamics of this trend can be attributed to governmental policy, commercialization of agricultural production, and rapid integration of Thai agriculture into the world market.[138] Thailand's Office of Agricultural Economics estimated in 1995 that the income of the population working in the agricultural sector was about fifteen times lower than the income outside of the sector. It was also found that the national average household income in 1999 was 12,729

[135]Ibid., *passim.*

[136]Ibid., 37 – 39.

[137]LePoer, *Thailand*, xv.

[138]Bello, et al., *A Siamese Tragedy*, 134.

*baht*[139] (US $318.00) per month, while the average income for farming households was no higher than 1,000 *baht* (US $24.00) per month.[140]

The shortcomings following the introduction of modern agricultural techniques have been the subject of a ten-year research project on the disappearing rice culture in the Central Plains of Thailand. Ngampit Satsanguan, who conducted the research, said that many farmers have found their economic hardship no longer bearable and wanted to call it quits.[141]

The research cited the case of Ayutthaya province, where a long history of rice farming was coming to an end, and may not exist in the next thirty or forty years. Satsanguan said that this is also happening in other parts of the Central Plains and several other provinces around the country. Mounting debt resulting from low paddy prices has caused many rice farmers to give up, and they have made it clear to their children that they do not want them to face the same fate. Out of 150 families, only thirty-seven still continue to cultivate rice in Phachi district, Ayutthaya. Most of the rice farmers are quite old, younger farmers are middle aged, and when they are gone there will be no one to replace them.[142] These realities of poverty have come to command the farmers' perception of their natural environment. Farmers are often very reluctant to invest scarce financial resources in improving the quality of their farms by using fertilizers and

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[139]The *baht* is the basic unit of Thai currency. Approximately 39.5 *baht* equal US$1.00.

[140]Rebeca Leonard and Kingkorn Narintatakul Na Ayutthaya, "Taking Land From the Poor: Giving Land to the Rich," *Watershed* 8 (2003): 14.

[141]Ploenpote Atthakor, "Debt Burden Leads to Sharp Drop in Number of Farmers," *Bangkok Post* (Accessed online January 21, 2003). Available: http://www.bangkokpost.com

[142]Ibid.

pesticides,[143] and through the maintenance of fields and drainage and irrigation channels, because of the danger that flooding or some other catastrophic event would wipe out their investment.[144]

## Land Use and Land Cover Change

Historically, E. Seidenfaden describes Thailand as richly endowed with fauna and flora, no less than seventy percent forest cover, "with vast expanses of valuable timber of considerable qualities and abundance."[145] Observing logging operations, Seidenfaden notes that "[t]he exploitation of this fine timber has occupied thousands upon thousands of men and animals for the last eighty years, European and Thai forest officials by the hundreds, and native laborers by the thousand,… [with their] elephants of which several thousand at present are working in the forests."[146] In the journals of Europeans visiting Thailand in 1850, it appears there were more than 100,000 elephants in the kingdom at a time when the human population was only five million. In 1900, a report from the Ministry of Interior states that there were still about the same number of elephants, ninety percent of them living in forests, in all provinces with the exception of those nearest the capital.[147]

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[143]Rigg, "The Role of the Environment," 490.

[144]Parnwell, "Rural Poverty, Development and the Environment," 205.

[145]E. Seidenfaden, *The Thai Peoples* (Bangkok: The Siam Society, 1958), 76.

[146]Ibid., 85

[147]Robert Mather, World Wildlife Fund Thailand, personal communication, November 28, 2002.

The close of World War II brought new technologies, especially the introduction of mechanized logging equipment and heavy machinery for road building. The technology decimated the environment within only two or three decades. By 1961, the kingdom still retained about fifty-three percent forest cover. However, since that time, deforestation has been more rapid than in any other country in the region other than Nepal.[148] Statistics vary on the percentage of the country now considered to be in forest between the sixteen percent estimate of the National Environment Board and the figures of roughly twenty-seven percent given by the Royal Forestry Department (RFD).

Much of the difference relates to the interpretation of the state, or status of various forest types. For example, some authors have gone so far as to say that "virtually all forests in Thailand have been cleared at some time in history, and most may have been cleared many times."[149] This observation is diametrically opposed to the RFDs 2001 estimate of more than 343,000 km$^2$ of total land base in the kingdom being under natural forest.[150] Additionally, many reforestation projects in Thailand that were set up to maintain twenty-five percent of the land in protected forest, "are nothing more than teak plantations, propping up an ailing government bureaucracy."[151] Many national parks and

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[148]Philip Dearden, "Environmental Protection and Rural Development in Thailand: Challenges and Opportunities," ed. Philip Dearden in *Environmental Protection and Rural Development in Thailand: Challenges and Opportunities*, Studies in Contemporary Thailand, No. 11 (Bangkok: White Lotus Press, 2002), 13 – 14.

[149]Peter K. Hansen, "The Forest as a Resource for Agriculture," in *Forest in Culture – Culture in Forest: Perspectives from Northern Thailand*. eds. Ebbe Poulsen et al. (Tjele, Denmark: Danish Institute of Agricultural Sciences, 2001): 149.

[150]Royal Forest Department, Forest Resources Assessment Division, Excel Workbook "Table 1: Preliminary Forest Land Use Assessment in 2000" (Accessed online February 10, 2005). Available: http://www.forest.go.th

[151]Richard Lair, Foreign Relations Officer – Northern Forest Industry Division, Forest Industry Organization – Lampang, Thailand, personal communication, December 5, 2002.

wildlife sanctuaries include considerable degraded and cleared forests. Some, instead of containing natural habitats for wildlife, actually include large areas of agricultural lands, human settlements, roads, dams, mines, and other intrusions.[152] It is estimated that around twelve million people live in the forestlands of Thailand, with a significant percentage of these occupying vast areas of national parks and wildlife sanctuaries. While these areas are protected under the Wildlife Preservation and Protection Act of 1992, which prohibits hunting, fishing, burning, logging, encroaching, and grazing, the reality is that all these activities are ongoing and seriously threaten wildlife populations and the environment.[153]

In 1989, severe flooding and landslides took the lives of some 300 people in southern Thailand, prompting the government to enforce a total ban on commercial logging. In the seven years following the ban, deforestation rates held at 1.2 percent annually, the same as before the ban was enforced. In the fifteen years before 2002, Thailand has gone from a major exporter to an importer of timber from around the region.[154]

Agricultural land occupied over sixty percent of the kingdom in 1998. Evergreen, deciduous, and plantation forests accounted for an additional 27.5 percent of land, while wetlands occupied 2.91 percent, mines and pits 1.78 percent, water bodies 4.47 percent, urban and built-up areas 1.67 percent, and other land uses 1.55 percent.[155]

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[152]Pattanavibool, RFD, personal communication, November 21, 2002.

[153]Ibid.

[154]Dearden, "Environmental Protection and Rural Development in Thailand," 14.

[155]Agricultural land includes paddy fields, field crops, perennial crops, orchards, horticulture, swidden cultivation, rangeland, urban agriculture, pasture, and farm houses. Others include abandoned land, marsh land, swamps, rock-outcrops, and beaches.

## Arable Land

According to the Central Intelligence Agency (CIA), arable land constitutes about thirty-three percent of Thailand's total land area, down from forty percent in 2002. "Arable land" is defined by the CIA as land cultivated for crops that are replanted after each harvest (thirty-three percent), such as rice, wheat, and maize; and land cultivated for permanent crops (seven percent), such as citrus, coffee, and rubber. The remaining sixty percent of land is classified as "other," and includes land under commercial development for trees grown for wood or timber; permanent meadows and pastures; forests and woodlands; and developed areas, such as roads, railroads, and urban areas.[156]

A more detailed analysis of land in the kingdom reveals that only about 6.6 percent of the total land area is considered relatively free of major constraints to agriculture, and that this land would remain highly productive for many more generations.[157] The study further found that twenty-six percent of the total land area had some major constraints that would require better than low, off-farm input to maintain sustainable production. The remaining 67.4 percent of land was considered fragile, and it was recommended that most of it should be kept out of agricultural production.[158]

While it would be hazardous to draw further conclusions from this study without spatial analysis at a local scale, it is interesting to note that 31.5 percent of the kingdom's total area is under cultivation (Table 6).

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[156]Central Intelligence Agency, *The World Factbook 2003.*

[157]Moncharoen, et al., "Land Resource Constraints for Sustainable Agriculture in Thailand," 179.

[158]Ibid.

Table 6. Total Land Area under Cultivation (*rai*)

| Region | Total area | Rice | Field crops | Vegetables, Flowers, Ornamental | Permanent crops |
|---|---|---|---|---|---|
| Whole Kingdom | 101,900,740 | 65,786,834 | 25,319,012 | 1,121,161 | 9,673,733 |
| Central | 21,426,649 | 10,826,521 | 7,120,369 | 402,337 | 3,077,422 |
| North | 24,215,627 | 14,551,860 | 7,483,324 | 351,918 | 1,828,525 |
| Northeast | 49,427,365 | 37,292,983 | 10,655,442 | 318,413 | 1,160,527 |
| South | 6,831,099 | 3,115,470 | 59,877 | 48,493 | 3,607,259 |

*Source*: National Statistical Office, *2003 Agricultural Census*.
Note: Total area in square kilometers under cultivation = 163,041 (31.5 percent of total land area)

## Land Tenure

From early times to about the middle of the eighteenth century, small-scale subsistence farming was the predominant feature of the Thai rural sector. Farming was directed at meeting the basic needs of the family, and surplus, if any, was for barter or for tribute to local elites. Land was abundant and access to land was secured through usufruct rights granted by the king.[159] Under usufruct rights, land had to be cultivated for at least three years, or could be taken back by the crown; otherwise it could be passed onto heirs, mortgaged, or sold. In 1901, by royal decree, King Chulalongkorn (Rama V, 1868 – 1910) differentiated between occupancy and legal ownership, leading to confusion and subsequent revision of law related to tenure in 1936, and again in 1954.[160] The 1954 legislation recognized a five step certification system to legally acquire land (Table 7).

[159]LePoer, *Thailand*, 147.

[160]Toru Yano, "Land Tenure in Thailand," *Asian Survey* 8 (1968): 853.

Table 7. 1954 Certificate Procedure for Legal Land Tenure

| Certificate | Significance | Issuing body | Inspection | Survey | Disposition |
|---|---|---|---|---|---|
| *soo.khoo.*1: | Certificate confirming land occupancy | District | No | No | No |
| *bai coong*: | Certificate for temporary occupancy of unused land. | District | Yes | Yes | Yes |
| *noo.soo.*3: | Certificate to confirm utilization of land. | District | Yes | No | No |
| *bai tai suan*: | Certificate for inspection and survey for issuance of *channot.* | Land Development Department | Yes | Yes | No |
| *chanoot thiidin*: | Certificate by which the state formally approves legal ownership. | Provincial Governor and Land Development Department | Yes | Yes | Yes |

*Source:* Yano, "Land Tenure in Thailand," 854.

Toru Yano conducted a survey of farmers[161] and found that about eleven percent of the farmers did not apply for *soo.khoo.*1, while about eighty-nine percent had *soo.khoo.*1, but no other certificates. Yano explains that many farmers held to their traditional concepts of usufruct rights, and considered *soo.khoo.*1 as if it were legal deed. In fact, some farmers did mortgage and sell land giving *soo.khoo.*1 that was accepted.[162] Yano attributes the lack of other certificates to ignorance of registration procedures, or

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[161]Yano conducted a random-sample survey consisting of 201farming households in southern Thailand from May 1964 to March 1966.

[162]Yano, "Land Tenure in Thailand," 855.

complete disregard for the purpose of tax evasion. Other problems inherent in the law were that the *soo.khoo.*1 certificate was issued on oral application, without inspection or survey (Table 7). This led to other issues concerning the accuracy of the land described, and mistakenly claiming land that was already tenant or in holding.

The issuance of title deeds proceeded slowly, and by 1960 government surveys showed that the total number of holdings, including tenants' households, had reached one million, although there were reported to be 3.4 million agricultural households in the kingdom.[163] In 1976, a government estimate placed the proportion of farm holdings having formal title at about sixty percent. For the remaining forty percent, lacking full title created a sense of insecurity for the farmer and presented a barrier to securing needed credit.[164] Insecurity led to unrest, as many farmers lost their land to creditors or sold it to get money to pay their debts-in effect becoming landless, or tenant farmers, on land that was once their own.[165]

Dispossession increased as commercialization of the agricultural sector further developed and became more profitable. By the early 1980s, it was estimated that the number of landless farmers in the kingdom was between 500,000 and 700,000.[166] Aristocratic families took advantage of small independent farmers' ignorance of the 1954 legislation to transcend their rights over labor, to rights over land of subsistence farmers.[167] Unrest and discontent grew among tenant and landless farmers, and erupted

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[163]LePoer, *Thailand*, 148.

[164]Ibid.

[165]Bello et al., *A Siamese Tragedy,* 140.

[166]LePoer, *Thailand*, 154.

[167]Bello, et al., *A Siamese Tragedy,* 139.

in demonstrations in 1974, leading to the Agricultural Land Reform Act of 1975 (ALRA75).

## Land Reform

The 1975 legislation established the Agricultural Land Reform Office (ALRO) marking the first time in the kingdom's history that a land reform agency had been created under its own identity with specific objectives. Section four of ALRA75 defines land reform as:

> Redistribution of land for farming and residential uses by allocating state land or land purchased or expropriated from landowners who do not themselves cultivate or who own land in excess of what is stipulated by the Agricultural Land Reform Act of 1975 to farmers who are landless or do not have sufficient land for cultivation, and to farmers' institutions by means of lease and sale. In so doing, the state will provide supporting services such as resource development, marketing facilities as well as public utilities.[168]

ALRO has four main objectives in implementing land reform: 1) To convert tenant and landless farmers into owner-operators, 2) to provide land ownership to squatter farmers through legalization and land distribution, 3) to increase agricultural production and improve delivery systems of supporting services to ensure better living standards among the farmers, and 4) to reduce social and economic inequalities among the populace.[169]

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[168]Suthiporn Chirapanda, *The Thai Land Reform Programme* (Bangkok: SEAMEO Secretariat, 1998), 18.

[169]Ibid., 19.

The beneficiaries of the reform act are defined as farmers with agriculture as their main occupation; those farmers who are landless and willing to work on a farm as their main occupation; and individuals who are either poor, a graduate in agriculture, or an offspring of a farm family. If found eligible, the farmer could receive no more than fifty *rais* for cropping, or no more than 100 *rais* for animal husbandry. In addition, land received under the reform program could not be sub-divided or transferred, except through inheritance, to farmers' institutions or to the ALRO.[170]

The act further stipulated that current owners can retain twenty *rais* (3.2 hectares), but land in excess, if not used for agricultural purposes, could be purchased or expropriated by the government and redistributed. The owners who fell under this stipulation were allowed to petition to retain more than fifty *rais*, but not more than 1000 *rais*. They were further obligated to prove that the land had been cultivated at least one year prior to the enactment of the legislation and that they possessed all farm implements necessary to cultivate the requested amount of land, and would do so themselves. Failure to comply with these conditions could lead to government purchase or expropriation at a later date.[171]

After successive coups in 1976 and 1977, the ALRA75 emerged with different objectives based upon the belief that the most pressing problem was the large number of people who had encroached upon state forest land. This new objective appeared easier to attain by the ALRO, rather than acquisition of land that was strongly opposed by large land owners, wealthy aristocrats, businessmen, and senior military officers. By 1978,

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[170]Ibid., 22.

[171]Ibid., 20 – 21.

some 320,000 hectares of public land had been distributed and more was being allocated. However, the 1975 legislation did not help the independent farmers as intended.[172]

Land holding statistics from Thailand's 2003 Agricultural Census indicate that the total number of holdings was approximately 5.8 million.[173] The Northeast Region occupied the largest number of holdings, with 2.6 million, or 45.6 percent of the total. This was followed by the North, Central, and Southern regions with 23.6, 15.6, and 15.2 percent respectively. The land area[174]of holdings totaled 114.5 million *rais*, or about thirty-six percent of the total area of the country. The Northeast Region occupied the largest area of holdings, with about fifty-two million *rais* (45.4 percent), followed by the North, Central, and Southern regions with 22.1, 19.1, and 13.4 respectively. The average area per holding for the kingdom as a whole was 19.8 *rais*-the Central Region having the largest average at 24.3 *rais*, and the Southern Region having the smallest average area at 17.3 *rais* (Table 8).

In the mid-twentieth century, statistical data on tenancy varied considerably and problems of classification led to different conclusions. A debate as to whether the full owner class should be included in the part-owner tenant class resulted in a stratification of census tenure data and official definitions. Land tenure evolving from the 1954 certificate system now takes many forms, employing varying deeds of title.

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[172]LePoer, *Thailand*, 152 – 153.

[173]A holding, as defined by the Thai National Statistical Office, is an economic unit of agricultural production that includes cultivating crops, rearing livestock, and fresh water culture. The holding is under single management comprising all livestock kept and all land used wholly or partly for agricultural production purposes, without regard to title or legal form.

[174]The area of a holding can consist of one or more parcels, located in one or more separate areas of the same province. The area of a holding is defined by the combined area of all the holding's parcels in the province, including land owned by the holder, rented from others, and land under other tenure arrangements. The holding area includes farmyards, land occupied by farm buildings, and the holder's house located on the holding.

Table 8. Number and Area of Land Holdings by Region in 2003

| Region | Number of Holdings | | Area of Holdings (rai) | | Average Area per Holding (rai) |
|---|---|---|---|---|---|
| | Number | Percent | Area (rai) | Percent | |
| Total | 5,782,519 | 100 | 111,460,932 | 100 | 19.8 |
| North | 1,367,702 | 23.6 | 25,346,792 | 22.1 | 18.5 |
| Central | 901,027 | 15.6 | 21,869,432 | 19.1 | 24.3 |
| Northeast | 2,640,866 | 45.6 | 51,835,157 | 45.4 | 19.7 |
| South | 882,924 | 15.2 | 15,309,551 | 13.4 | 17.3 |

*Source*: National Statistical Office, *2003 Agricultural Census.*

One holder may own land outright (full owner), while other owners may hold documentary right of land, but are not yet recognized as full owners. A holder is now defined as either a civil or juridical entity who exercises management control over an agricultural holding. The holder is responsible for the technical and economic operation of the holding, but may delegate responsibilities to a hired manager. The hired manager responsible for the holder's obligations is considered a holder. A holder can also be considered to be an owner of land if he has occupied that land and cultivated it continually for ten years or more. Documentary rights are also recognized under mortgage certificates and sales with right of redemption. It is therefore somewhat challenging to interpret some Thai statistics when all forms of tenure are not explicitly defined, such as "others." "Others," as defined by NSO "...refers to all types of tenure not covered by above forms." However, there is confidence that while a holder may take many forms, the NSO makes it clear that they do differentiate and are not repetitive. In light of this, Table 9 gives some insight into percentages of differing land tenure by region.

Table 9. Percentage of Holdings by Land Tenure and Region in 2003

| Land tenure | Total | North | Central | Northeast | South |
|---|---|---|---|---|---|
| Full owner | 71.7 | 61.5 | 57.9 | 76.6 | 86.9 |
| Own | 74.0 | 63.2 | 59.5 | 78.6 | 91.5 |
| Rent | 7.8 | 11.7 | 18.5 | 4.5 | 1.2 |
| Other | 11.2 | 16.1 | 22.6 | 7.5 | 3 |

*Source*: National Statistical Office, *2003 Agricultural Census.*

Table 9 shows that in 2003 seventy-four percent of the land was operated under the definition of "own," while 7.8 percent was "rent," and 11.2 percent operated under a variety of "other" land-tenure forms. A comparison of the percentages of full owners in the Southern and Northeastern regions in 2003 to those surveys taken in 1973 – 1974 (Table 10) reveals a 3.9 percent increase and a 12.4 decrease of full owners in these regions respectively. More significant are increases in those operating under "own" in these two regions. This designation has increased in the south and northeast, and stands at 75.5 and 70.6 percent respectively. During this same period (from 1974 to 2003), the Northern and Central regions also witnessed a growth of full owners at 34.2 and 19.5 percent respectively. These trends could indicate levels of entitlement or a rising number of landless farmers.

Table 10. Percentage of Holdings by Land Tenure and Region in 1974 - 1975

| Land tenure | North | Central | Northeast | South |
|---|---|---|---|---|
| Full owner | 69 | 60 | 89 | 83 |
| Own | 29 | 40 | 8 | 16 |

*Source*: LePoer, *Thailand,* 150 – 151.

Land reform and reallocation are still very contentious issues in Thailand. Recently, ALRO has announced that it will propose amendments to the ALRA75 in order to better deal with the reality of current conditions. However, Phairoj Pholphet, a land-rights expert for the Union for Civil Liberty, has accused ALRO of proposing the amendment to solve its own problems rather than those of the farmers. Pholphet contends that the amendment would enable sales of reform land with the result being that the rich would take advantage of the poor farmers whom the office had tried to help.[175] As one observer has noted "…the process to reallocate land to the rural poor under provisions of [ALRA75], has become rife with corruption, cronyism, scandals, misappropriations, and has almost completely overwhelmed the good intentions of the legislation."[176] A detailed study of one district in Nakhon Ratchasima Province is a case in point. The study revealed that the sixty-nine largest landholders in the district owned a total of about five thousand hectares in total. While the landholders did comply with the fifty *rai* limit, as stipulated by the land reform act, they were found to be in possession of dozens or hundreds of deeds, allowing their overall limit to substantially exceed that allowed by law (Table 11).

Land-reform policy still faces many challenges and has been plagued by several problems-mostly in the implementation of the program. Additionally, political will has not been consistent or steady throughout successive administrations, causing further objectionable consequences.[177] Nevertheless, ALRO says that about 1.6 million farmers have benefited from the program as of 2004. Fifteen million *rais* of farm land were distributed, twenty-five million more *rais* are slated for allocation.

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[175]Piyaporn Wongruang, "Titles Could Be Transferable," *Bangkok Post* (Accessed online February 5, 2005). Available: http://www.bangkokpost.com

[176]Bello, et al., *A Siamese Tragedy,* 152 – 156.

[177]Chirapanda, *The Thai Land Reform Programme,* 42.

Table 11. Concentration of Landholdings in Nakhon Ratchasima Province

| Landholder | Number of deeds held | Average size of landholding per deed (rai) | Approximate total (rai) |
|---|---|---|---|
| 1 | 83 | 33.57 | 2,787 |
| 2 | 159 | 12.93 | 2,055 |
| 3 | 45 | 42.91 | 1,931 |
| 4 | 86 | 21.92 | 1,885 |
| 5 | 63 | 17.73 | 1,117 |
| 6 | 60 | 18.45 | 1,107 |
| 7 | 42 | 20.89 | 878 |
| 8 | 105 | 7.84 | 823 |
| 9 | 257 | 2.99 | 767 |
| 10 | 45 | 15.5 | 698 |

*Source*: Leonard and Ayutthaya, "Taking Land From the Poor," 23.

The office further expects to distribute three million *rai* to about 190,000 landless farmers in 2005.[178]

[178]Kultida Samabuddhi, "Land Reforms: 190,000 Farmers to Get Plots," *The Nation*. (Accessed online February 27, 2005). Available: http://www.nationmultimedia.com

CHAPTER 4

# IMPROVING THE AGRICULTURAL PRODUCTIVITY OF THAI SOILS

## Literature Review

A number of studies have addressed issues of soil fertility in Thailand at differing spatial scales, with differing methodologies and objectives, and have recommended experimental actions with a number of chemical fertilizer rates and management practices. For example, Andrew Hall and Norman Clark[179] studied the effectiveness of the Rhizobium Inoculants Production and Promotion Program implemented by the Thai Ministry of Agriculture in 1983. Hall and Clark's results showed considerable regional variation in the effectiveness of inoculation, in terms of yield, associated income benefits, and farmers' willingness to adopt the technology. In the case of Maharsharkarm Province, the study revealed only marginal benefits in yield-to-production-cost ratio and income. The study also suggested that the effectiveness of inoculation decreased over time in the region with the longest history of Rhizobium use. This conclusion was inferred from an area where yield responses indicated that there were no statistically significant differences between yields of farmers using, and those not using, inoculants over three cropping seasons.[180] Hall and Clark conclude in part: "What seems unavoidable, however, is the conclusion that if the Rhizobium inoculants story [in

[179]Andrew Hall and Norman Clark, "Coping with Change, Complexity and Diversity in Agriculture – The Case of Rhizobium Inoculants in Thailand," *World Development* 23 (1995): 1604.

[180]Ibid., 1605.

Maharsharkarm Province] is in any way typical of Third World agriculture, then some fresh thinking on the organization of relevant scientific research is well overdue."[181]

In another study by Matsumoto et al.,[182] experiments with various organic-matter applications under till and no-till cultivation were carried out in Khon Kaen Province from 1990 to 1992. The objective of the study was to identify the dynamics of organic residuals as related to N cycles and nutrient balance. Nutrient stocks in the soil were expected to increase with the additional biomass under no-till cultivation. A quantitative analyses was carried out to determine locally available sources of organic biomass and to develop a model to estimate the N cycle for crop production. As a baseline for the study, under current cultivation practices, it was estimated that existing N stock in the soil was approximately 1200 kg N/ha. From input-output analysis, it was determined that the N budget represented a loss of 40 kg N/ha/year.[183] Two test plots were established: 1) a control plot under tillage employing current practice, and 2) a plot under no-tillage. The control plot was tilled, sown with maize, and amended with cow dung and 18 kg/ha/year of chemical N fertilizer. The second plot under no-tillage was cultivated with cowpea as a source of green manure before sowing maize. The plot was then amended with rice straw, bagasse, and 18 kg/ha/year of chemical N fertilizer. While soil N stock increased in both plots, soil carbon stock under tillage decreased, and soil carbon stock under no-tillage increased. Cowpea incorporation in plot 2 showed only a slight increase in N,

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[181]Ibid., 1612.

[182]Naruo Matsumoto, Kobkiet Paisancharoen, Chairoj Wongwiwatchai, and Prapai Chairoj, "Nitrogen Cycles and Nutrient Balance in Agro-Ecosystems in Northeast Thailand," in *Development of Sustainable Agricultural System in Northeast Thailand through Local Resources Utilization and Technology Improvement*, ed. Osamu Ito and Naruo Matsumoto, JIRCAS Working Report No. 30 (Tsukuba, Ibaraki, Japan: Japan International Research Center for Agricultural Sciences, 2002), 49 – 53 (Accessed online November 30, 2002). Available: http://ss.jircas.affrc.go.jp

[183]Ibid., 50.

while cow dung in plot 1 was thought to have maintained the N balance. Rice straw was thought to have supplied large amounts of N and K, while the application of bagasse showed only a limited contribution to nutrients. Nutrient loss in both plots was shown to be about the same. The study suggests the need for follow-up research on its findings in order to better assess benefits that could be realized by long-term implementation of the proposed management practices. The study further recommended returning more crop residues and cow dung to farmland, but was left with the issues of how to apply residues and increase the supply cow dung.

Anthony Whitbread and his colleagues experimented with leaf litter, rice straw, and high/low applications of chemical fertilizers for rain-fed rice cropping systems.[184] The findings indicated that, while net positive balances of N and P were observed, S and K balances resulted in net deficits.[185] It was also found that significant increases in total carbon content only occurred when rice stubble was applied, in combination with high rates of chemical fertilizer.[186] In another study by Watson,[187] experiments with *Sesbania* as a green manure were tested on ten demonstration plots over a three-year period. Each plot was comprised of four different treatments per farm. The first three treatments consisted of *Sesbania* with increasing amounts of fertilizer, followed by rice with no fertilizer; the fourth treatment was fallow followed by rice with a high application of fertilizer (150 kg/ha N-P- K, 16-16-8 fertilizer, the usual amount applied by farmers in

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[184]Anthony Whitbread, Graeme Blair, Yothin Konboon, Roy Lefroy, and Kunnika Naklang, "Managing Crop Residues, Fertilizers and Leaf Litters to Improve Soil C, Nutrient Balances, and the Grain Yield of Rice and Wheat Cropping Systems in Thailand and Australia," *Agriculture, Ecosystems and Environment* 100 (2003): 251 – 263.

[185]Ibid., 251.

[186]Ibid., 261.

[187]Watson, "Soil Organic Matter Management in Thailand," 206 – 214.

the area.) *Sesbania* was sown and allowed to grow for six to eight weeks before being plowed in before transplanting rice. The trials showed that the average rice yield increased under *Sesbania* with increasing fertilizer application, ranging from 2.24 tons per hector to 2.53 tons per hectare, compared to treatment four which was 1.89 tons per hector. The *Sesbania* findings represent a significantly higher yield than the farmers' own yield at a probability of 0.1 percent.[188] Small changes in soil pH were detected after incorporation of *Sesbania*, while no consistent changes were evident in soil organic matter, with total carbon varying between 0.3 and 0.6 percent. A cost-benefit analysis, comparing treatments with lowest and highest fertilizer applications, revealed a clear economic benefit from using *Sesbania* compared to the farmers' normal rate of fertilizer. Despite the economic benefits, the author points out some socioeconomic drawbacks that contributed to some farmers discontinuing the demonstrations: 1) Farmers were too busy at the beginning of the rains to divert their time to sowing *Sesbania*. 2) Some *Sesbania* plants continued to grow in the following rice crop and acted as weeds. 3) Seeds were not readily available and would be costly in land diversion from rice, were farmers' to grow them themselves.

The studies cited above, and others, generally show marginal success in improving soil fertility and achieving sustainability.[189] Research to improve infertile soils in Thailand are mainly centered upon experiments to better manage and increase

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[188]Ibid., 212.

[189]Other approaches taken to alleviate the problems faced by Thai farmers, is conversion to organic farming. Without the use of expensive chemical fertilizers, production costs are lowered, thereby allowing the farmers to invest in fishponds, animal husbandry, and equipment. Diversifying the agro-ecosystem can potentially bring sustainability and improved soil fertility. Farmers who have converted to organic practices report better health, lower medical expenses, higher yields, and the beneficial return of fish, frogs, crabs, insects, and plants to their fields. Oxfam, "Organic Rice Farming in Thailand" (Accessed online June 1, 2005). Available: http://www.oxfam.org.uk

biomass through animal manure, green manure, compost, crop residue, and other forms of organic biomass which are in short supply in the region. These studies do not take into account natural processes of soil formation, disregarding essential mineral and trace elements that are vital to the physical, biological, and chemical properties and processes of soils, which govern their fertility. This situation is reminiscent of the case of Rhizobium inoculants, where the authors suggest that a new direction in relevant scientific research is well overdue. To exemplify this point, Eswaran and his colleagues observe that:

> [i]t is ironic, but agronomists and soil-fertility specialists are often among those who are most ignorant of soil diversity in the tropics. Since the initiation of soil-fertility research decades ago, the same kinds of experiments have been conducted and repeated all over the world with no end in sight. The N-P-K trials keep an agronomist employed, which may be the reason why the experiments never end. In practically every country of the tropics, there is one fertilizer policy for the whole country that may date back to the independence of the country or dictated by a fertilizer supplier. Performance appraisal of the institution is based on the number of soil samples analyzed per year. If all the analyses over the last 50 yr were tabulated, it would not be surprising if essentially every arable soil in the country has been analyzed; yet the process continues.[190]

## Mineral Resources in Thailand

In 1996, the United States Geological Survey (USGS) released the Minerals Resources Data System (MRDS)[191] that contains georeferenced information regarding the

[190]Eswaran et al., "Soil Diversity in the Tropics," 9.

[191]George T. Mason, Jr., and Arndt, Raymond E., 1996, Mineral Resources Data System (MRDS): U.S. Geological Survey Digital Data Series DDS-20, U.S. Geological Survey, Reston, VA.

metallic and nonmetallic mineral resources of the world. MRDS contains descriptive information about mineral deposits, commodities, sites, mines, prospects, and occurrences. The Thailand subset of the database was created from the master MRDS database and identifies ninety mineral deposits throughout the kingdom.

For the purpose of this analysis, rocks and minerals with the greatest potential for utility in agricultural application were chosen from the data set. This resulted in the identification of thirty-four locations in the kingdom where geologic resources may be acquired for agricultural use. Figure 6 illustrates major rock types (fifteen sedimentary; fourteen igneous; and five metamorphic) and their location in the kingdom.

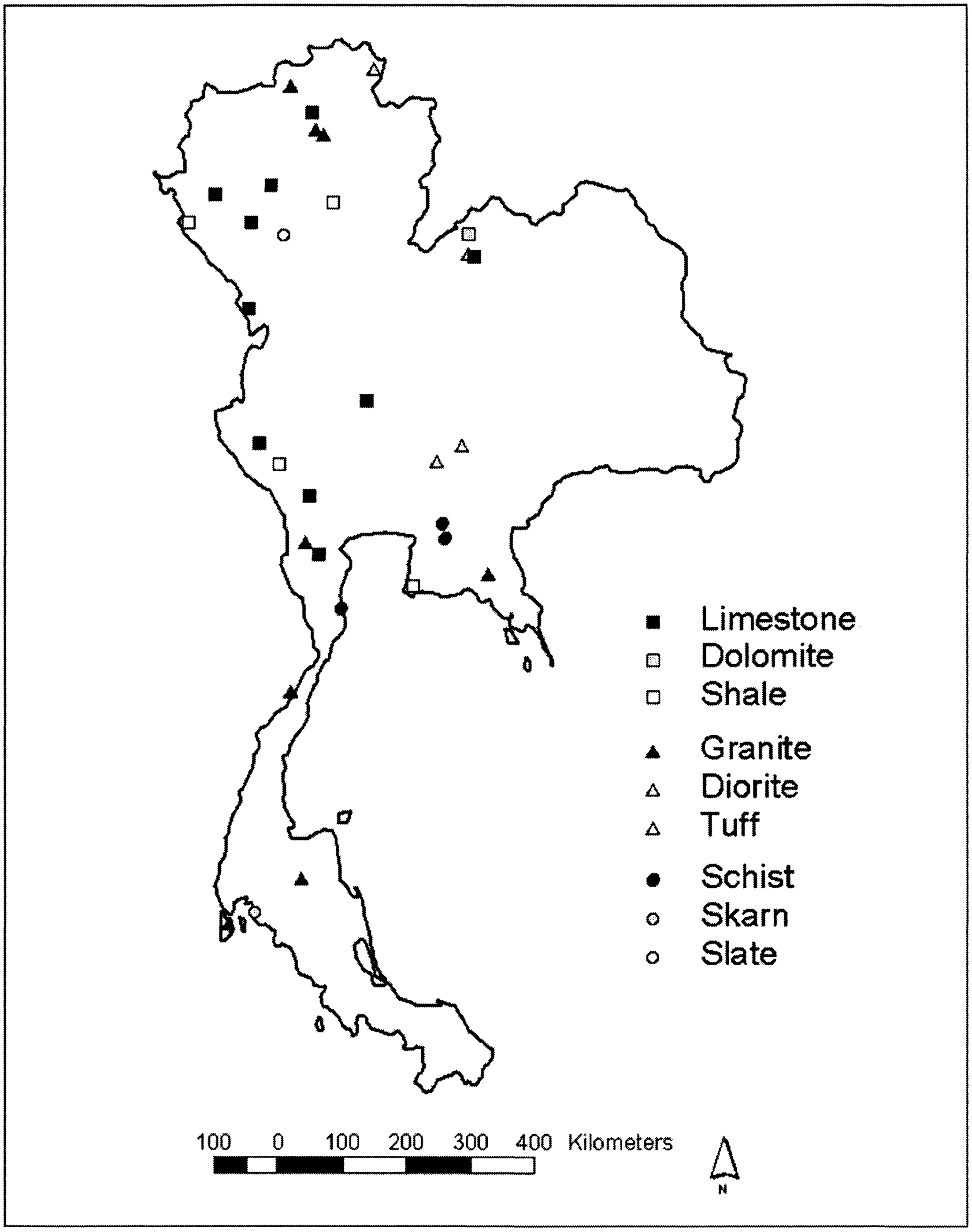


Figure 6. Location of Geological Resources in Thailand
*Source*: George T. Mason, Jr., and Arndt, Raymond E., 1996, Mineral Resources Data System U.S. Geological Survey Digital Data Series DDS-20, U.S. Geological Survey, Reston, VA.

## Discussion

In tropical rain-fed environments, native vegetation has evolved and adapted to a diversity of soils, varying rainfall regimes, and other environmental conditions. Tropical forests on poor soils have developed intricate mechanisms for holding minerals within the living tissues of vegetation and exist despite the soils, not because of them. Litter and humus on the ground are thin under high temperatures, abundant rainfall, and rapid rates of decomposition. If the forest is cut and burned, ash and decomposing vegetation can supply adequate nutrients to support herbaceous growth for two or three years. These materials then decline to levels lower than those needed to support agricultural crops without external inputs.[192]

Most agricultural soils in Thailand have been in continuous production for many decades, and past land use and management practices have had more influence on fertility than the type of soil itself. The already fragile and inherently infertile soils have more problems than a lack of biomass. As noted above, the natural processes of soil formation seem to evade the attention of researchers (Appendix). Given what is known about these processes, it is apparent that infertile Thai soils are at the end of their evolutionary life (Figure 8, Appendix). It seems reasonable to suggest then, that natural processes need to be considered in order to improve fertility. In this case, following nature's model where all elemental components are in place, starting from the parent material weathering process where rock minerals are transformed into soil material. This concept is outlined as follows:

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[192]E.O. Wilson, "The Current State of Biological Diversity," in *Biodiversity*, ed. E.O. Wilson (Washington D.C.: National Academy Press, 1988), 9.

Fertile soils contain approximately forty-five to sixty percent mineral matter, forming the basis of a complex and dynamic system of biological, chemical, and physical processes. Under these conditions, mineral matter serves as a nutrient reservoir for plants, enhancing permeability; aeration; structural, thermo, and hydro stability; and thus providing an environment where biological activity can thrive in a healthy system.

Of the seventeen essential plant nutrients that are elements known to be necessary for the growth of all plants, macronutrients are required in large amounts while micronutrients[193] are required in small to trace amounts.[194] With the exception of nitrogen, all plant nutrient resources are of geological origin. James Hutton, the father of modern geology, not only advocated their use, but used rocks himself to increase the soil fertility of his Scottish farm.[195] Several tens of theoretical and experimental studies, including laboratory tests, pot experiments, and field trials in Africa, Europe, North and Latin America, using finely ground and chemically unprocessed rocks and minerals, have supported the concept of their utility in agro-ecosystems.[196] Existing data from R. C. Severson and Hansford Shacklette,[197] Mikko Sillanpaa,[198] O. H. Leonardos and his

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[193]Macronutrients: Carbon (C), Hydrogen (H), Oxygen (O), Phosphorus (P), Nitrogen (N), Sulfur (S), Calcium (Ca), Potassium (K), Magnesium (Mg). Micronutrients: Boron (B), Chlorine (Cl), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Zinc (Zn).

[194]T. H. DeLuca and M. P. O'Herron, *Introductory Soil Science Laboratory Book*, Sixth Edition, School of Forestry, The University of Montana, Missoula, Montana, 2002 (unpublished), 5.

[195]Leonardos et al., "The Use of Ground Rocks in Laterite Systems," 362.

[196]O.H. Leonardos, S. H. Theodoro and M. L. Assad, "Remineralization for Sustainable Agriculture: A Tropical Perspective from a Brazilian Viewpoint," *Nutrient Cycling in Agroecosystems* 56 (2000): 5.

[197]R.C. Severson and Hansford T. Shacklette, "Essential Elements and Soil Amendments for Plants: Sources and Use for Agriculture," U.S. Geological Survey Circular 1017 (Washington, D.C.: Government Printing Office, 1988)

[198]Mikko Sillanpaa, *Trace Elements in Soils and Agriculture*, FAO Soils Bulletin 17, Food and Agriculture Organization of the United Nations, Rome (1979), 4 – 5.

colleagues; Fyfe and his fellow researchers; and Peter van Straaten, show that a whole variety of rocks could be successfully applied to agro-ecosystems. Leonardos' team contends that by putting inorganic compounds back into the soil, heavily leached and degraded soils of the tropics can be restored to the same nutrient levels of highly fertile younger soils.[199]

Rock containing essential macro and micro nutrients essential for plant growth can all be found in granite, rhyolite, sandstone, shale, limestone, dolomite, and a host of their component minerals that may be of viable utility for agriculture.[200] Severson and Shacklette point out that in areas of the world where agriculture is more people intensive than power intensive, using rocks as soil amendments may play a significant role in increasing agricultural production. They also cite limiting economic factors for the viability of rock amendments, such as geographical location; availability; and cost of transportation.[201] However, as van Straaten, Leonardos, and others have stated, local availability of useful rocks can often be found in the mining, gravel, and quarrying industries, sometimes already available in ground form, and considered a residual by-product or waste.[202] The consequences of not re-mineralizing soils are already evident in Thailand: falling and stagnant yields; decreased soil fertility; exacerbated soil erosion; heavy leaching; sterility; and land abandonment. Fyfe and his colleagues state that

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[199]Leonardos et al, "Remineralization for Sustainable Agriculture," 3 – 4.

[200]Severson and Shacklette, "Essential Elements and Soil Amendments for Plants," 2 – 36.

[201]Ibid., 36.

[202]van Straaten,, *Rocks for Crops*, 37; Leonardos et al., "Remineralization for Sustainable Agriculture," 7.

"...[U]nless Nature, through geological forces or Man, through the application of appropriate rock dusts, intervenes to restore nutrient balance...disaster is inevitable.[203]

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[203]Fyfe et al. "Global Tectonics and Agriculture," 383 – 399.

# CHAPTER 5

# CONCLUSION

Issues of soil fertility in Thailand are influenced by a broad range of factors dating back to the Mesolithic Period, during which Gorman believes evidence of human activity upon environmental systems began to show exploitative patterns. Centuries of migrating peoples continued to filter into the region, and as populations increased states developed, becoming more complex, and leading to an ever-increasing demand upon natural resources. The situation worsened in the late nineteenth and early twentieth centuries as populations continued to grow, and world markets for rice and timber emerged along with new technologies that devastated the environment. A positive correlation between forest loss and agricultural expansion on inherently infertile soils has caused many problems for the existing agrarian society and poses perplexing problems for governments and other institutions that seek to help them.

Tropical soils are fragile, and when the natural vegetation is removed may only support agricultural production for a few years. The forests have adapted to the natural variability of the physical environment over millions of years, having developed a complex and unique nutrient cycling system much different from that of an ago-ecosystem. Tropical forests hold most of their nutrients in tissue that is utilized before it can be lost to the system. In contrast, ago-ecosystems continually pull minerals from the system, their biomass being transported out of the system, consequently leaving no nutrients being returned to the soil.

It is understandable then, why so much research is centered upon experiments with biomass and chemical fertilizers, and it is also understandable why someone such as David Sims would be taking part in his own biomass experiment. Almost all life in the soil is dependent upon organic matter for nutrients and energy. Organic matter contributes to soil structure stability, water holding capacity, and cation exchange capacity. However, under the tropical conditions of highly weathered soils, and rapid decomposition of organic matter, nutrients are quickly leached from the system or run-off before they can be made available to vegetation. At the same time, organic matter is but one component of a soil, and is dependant upon inorganic materials. It is generally accepted that infertile Thai soils are depleted of their inorganic mineral base-the foundation of a productive soil system. The equilibrium of the system might first be gained through the addition of appropriate rock dust. Soil-forming processes are broadly understood, but the details to attain fertility are so complex that it is not possible to make an informed decision as to the amount of compost to be tilled into a given area without a more comprehensive analysis.

In a healthy soil, equilibrium between inorganic and organic materials provides a soil system where weathering and erosion are balanced and plant growth and biodiversity can thrive. Inherently infertile soils depleted of their inorganic elements lack the basic structure, and therefore the ability to function as a healthy soil system. The problem is manifest in the physical and chemical properties of the soil that inorganic elements-the mineral matter-provide. Nature has provided the resources necessary, and model for this concept through different geological processes. Outside of recent alluvium deposits, infertile soils in Thailand are found on geological materials that have been inactive for millions of years. Reminiscent of Fyfe, Leonardos, and others then, why cannot man act as a geological force and replenish the lost link, vital to the management and function of a healthy, fertile soil system?

# APPENDIX

## SOIL FORMING FACTORS

The themes discussed in Chapter 2-geology, geomorphology, climate, hydrology, and flora and fauna-are inherent in soil-formation factors; a result of the interaction of parent material, topography, climate, and organisms, over time. These relationships are described in Hans Jenny's Fundamental Soil Equation:[204]

$$s = f(cl, o, r, p, t, \ldots)$$

where *s* is the state of the soil, *f* indicates that *s* is a function of the following variables: *cl* is the climate, *o* is the activity of organisms, *r* is relief (landforms/topography), *p* is the parent material, and *t* is time. These soil-forming factors control various soil-forming processes that lead to the development of a particular soil type. With the exception of Pleistocene glacial formations such as till and loess, all of the rocks found in the tropics are also found in the temperate regions, and many pedogenetic processes, including mineralization, eluviation, and illuviation, are universal in nature.[205] Nevertheless, the degree to which some of the soil-forming factors work in the tropics, has produced extreme manifestations of soil types.[206] In light of Jenny's "*fundamental* equation of soil

[204] Hans Jenny, *Factors of Soil Formation. A System of Quantitative Pedology* (New York: McGraw-Hill Book Company, 1941), 16.

[205] Eswaran, et al., "Soil Diversity in the Tropics," 3, 8.

[206] Ibid., 8.

forming factors," the following discussion will briefly outline associated processes, and major principles involved, in order to better understand soils found in Thailand today.

## Parent Material

Parent material is the geological material upon which soils form. Parent material can be residual or transported. Residual parent material is bedrock that has weathered in place to form soil, while transported parent materials are unconsolidated materials that have been weathered, transported, and ultimately deposited by gravity, wind, water, or ice.[207] In the tropics, where no Pleistocene glaciation took place, many landscapes predate the Quaternary, and mid-Tertiary landscapes are not uncommon.[208] Geological stability, in many areas for millions of years, has produced highly weathered soils, in some cases from parent material that was highly weathered when it was deposited.

The weathering process is the first stage in the transformation of parent material into soil material. Weathering involves both mechanical and chemical processes, largely governed by the climate of a given area. Mechanical processes involve a physical reduction in the size of rocks permitting further modification and alteration of parent material. Several factors of mechanical weathering govern the rate at which soil is formed; such as temperature, rainfall, topography, and flora and fauna.[209] Chemical weathering is also influenced by mechanical factors in which the mineral components of

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[207]Donald Steila and Thomas E. Pond, *The Geography of Soils: Formation, Distribution and Management*, 2nd ed. (Savage, Maryland: Rowman & Littlefield Publishers, 1989), 5.

[208]Eswaran, et al., "Soil Diversity in the Tropics," 3.

[209]Steila and Pond, *The Geography of Soils, 6 – 7.*

rocks are further reduced in size, and the transformation of geological material into soil takes place.

The resultant soil type is highly dependant upon these weathering processes, but also significantly influenced by the composition of the parent material. Rock minerals do not all decay at the same rate, and the precise composition of parent material can vary widely. For example, Australian researchers have found that sandstone may vary in composition from ninety-five percent quartz with five percent clay, to sixty percent quartz with forty percent clay, with the nature of the clay minerals being quite different.[210] Taken together, the processes of weathering on different parent material can produce a great diversity of soil types, often observable within one farmer's field. The USDA Soil Taxonomic System, at the order level, indicates similarities of pedogenic processes that are largely based upon the degree of weathering. Figure 7 illustrates the relationship between soil orders and the degree of weathering, and further exemplifies the diversity of soils found in Thailand.

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[210]J.M. Gray and B.W. Murphy, *Parent Material and Soils: A Guide to the Influence of Parent Material on Soil Distribution in Eastern Australia,* Technical Report No. 45 NSW Department of Land and Water Conservation (Sydney: Crown, 2002), 89.

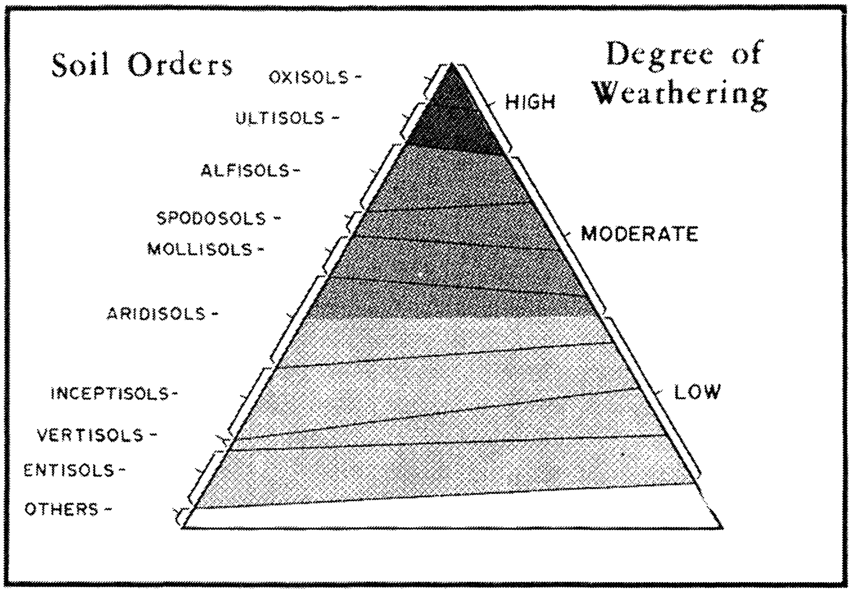


Figure 7. Relationship between soil orders and degree of weathering. *Source:* Steila and Pond, *The Geography of Soils*, 74. (Used with permission of publisher)

## Climate

The climatic factors of rainfall and temperature have a major influence on soil formation. For every 10 °C increase in temperature, the rate of chemical reactions increase approximately two times.[211] The soil temperature regime, defined as the difference between mean summer and mean winter soil temperatures of 5°C or less, are almost exclusively confined to the intertropical regions, and may be considered a soil property that sets tropical soils apart from all other soils.[212] The factors of rainfall and temperature combined influence the degree of weathering, degree of leaching of soluble bases, degree of translocation of clays, biotic activity, organic matter accumulation, and thus, potential for plant growth.[213]

[211]Foth, *Fundamentals of Soil Science*, 262.

[212]Eswaran, et al., "Soil Diversity in the Tropics," 1.

[213]Gray and Murphy, *Parent Material and Soils*, 4.

## Topography

The most direct role of topography in soil formation is to influence the drainage characteristics thereby governing the amount of water present in, and flowing through, the soil. In general, soils are thin on steep slopes where removal of loose surface materials is enhanced by the power of gravity and running water, and better developed on gentle slopes where net gains of materials from upper slopes accumulate.[214] Elevation, slope, and aspect also play critical roles in soil formation. Decreasing temperature and increasing precipitation with rise in elevation, slope, and aspect all affect soil water and temperature regimes, resulting in an altitudinal succession of soil types with differing features.[215]

## Time

The characteristics of a soil are very much dependent upon the period of time during which soil-forming processes, such as weathering, leaching, and particle translocation, have been operating. Well developed (mature) and undisturbed soils normally exhibit a sequence of horizons classified by pedologists as O, A, E, B, C, and R.[216] Figure 8 illustrates the evolution of soil horizons from youthful through mature.

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[214]Steila and Pond, *The Geography of Soils,* 54.

[215]Ibid., 55 – 57.

[216]Ibid., 60.

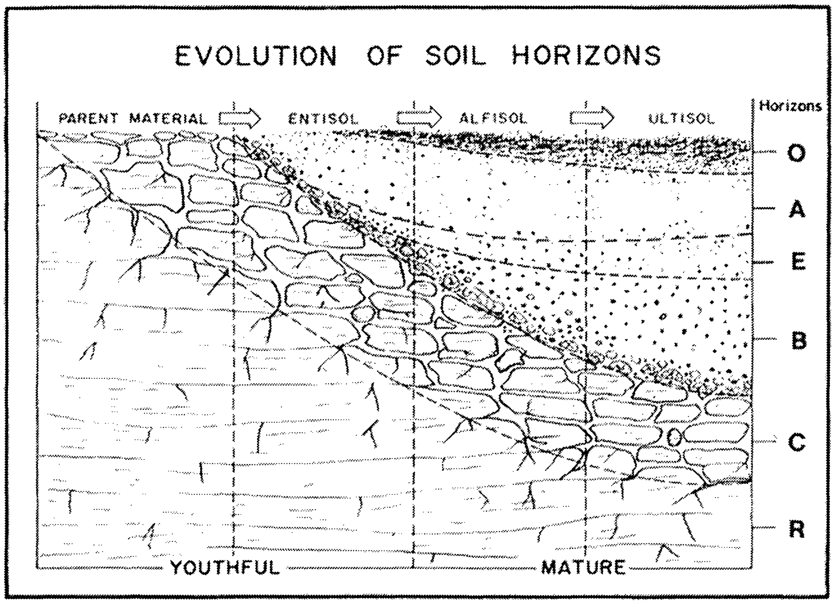


Figure 8. Evolution of Soil Horizons *Source:* Steila and Pond, *The Geography of Soils*, 60. (Used with permission of publisher)

As time proceeds and soil weathering and leaching processes continue, the chemical and mineralogical compositions of the soil diverge from the original parent material, eventually reaching an equilibrium state of high silica, aluminum, and iron, irrespective of the original composition.[217] In geologically inactive landscapes, without the influence of the original parent material, such soils generally equate to laterites, bauxite, or siliceous sands.[218]

## Bioactivity of Organisms

The dynamics of bioactivity in a soil system are integrated throughout Jenny's fundamental equation of soil-forming factors, and the critical importance of them cannot be underestimated. From very early stages of soil development, flora and fauna, both

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[217]Gray and Murphy, *Parent Material and Soils*, 89.

[218]Ibid., 8.

living and dead, contribute to weathering processes of parent material and chemical processes transforming essential minerals into elements available for plant growth. The diversity and areal extent of the flora and fauna is also governed by the composition of parent material, climate, and temporal factors, ultimately defining the properties of a given soil system.

Soil fauna, such as worms, ants, termites, and other microorganisms, are associated with improving soil structure and fertility through processes of cycling organic matter and nutrients. Litter breakdown is mainly the work of fauna, whereas the chemical deterioration of tissues is primarily microbial.[219]

Flora affects soils in numerous ways, including the provision of a protective cover that reduces the potential of erosion; enhances structure, aeration, and water holding capacity; and regulates soil temperature and moisture regimes. In effect trees, shrubs, and other flora act as "nutrient pumps," recycling nutrients from lower layers of soils to the surface. When flora dies, its mass is returned to the nutrient cycle, enhancing the floral and faunal activity vital to the soil system. Microfloras are also important to the soil system, consisting primarily of bacteria, fungi, actinomycetes, and yeasts.[220] Their main effects upon mineral transfer are through temporary immobilization and subsequent release of minerals in ionic forms available to higher plants.[221] The dynamics of the physical, biological and chemical processes outlined here, develop and sustain the soil

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[219]Witkamp, "Soils as Components of Ecosystems," 91.

[220]Ibid., 94.

[221]Ibid.

system in terms of its potential nutritional support of different life forms in the biotic pyramid of microbes, plants, animals, and man.

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